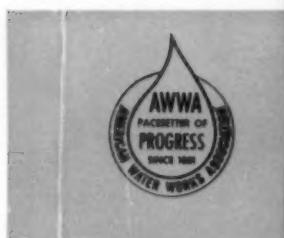


OCTOBER 1960



VOL. 52 • NO. 10

J

Journal

AMERICAN
WATER WORKS
ASSOCIATION

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all set to arrest
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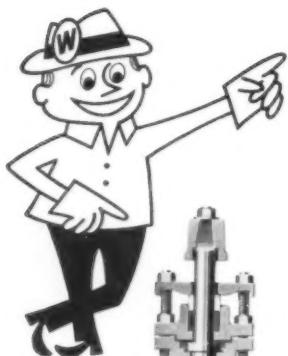
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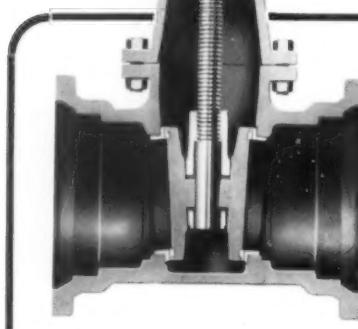
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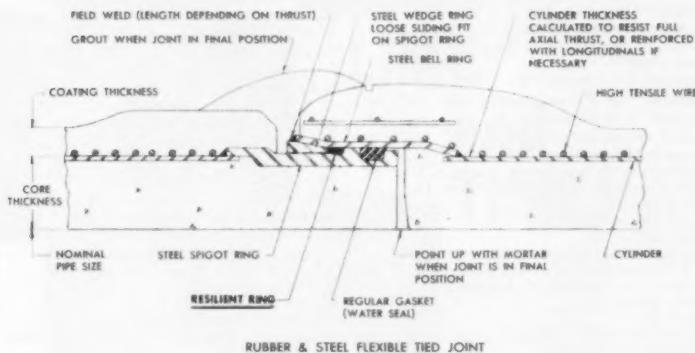
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Coming Meetings

AWWA SECTIONS

Oct. 16-19—Southwest Section, at Galvez Hotel, Galveston, Tex. Secretary, Leslie A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 19-21—Iowa Section, at Fort Des Moines Hotel, Des Moines. Secretary, J. J. Hail, Supt., Water Dept., City Hall, Dubuque.

Oct. 20-22—New Jersey Section, at Madison Hotel, Atlantic City. Secretary, A. F. Pleibel, Dist. Sales Mgr., R. D. Wood Co., 683 Prospect St., Maplewood.

Oct. 24-27—Rocky Mountain Section, at Broadmoor Hotel, Colorado Springs, Colo. Secretary, Harrison F. Kepner, Vice-Pres., Dana Kepner Co., 550 Alcott, Denver, Colo.

Oct. 25-27—California Section, at Lafayette Hotel, Long Beach. Secretary, F. F. Watters, Hydr. Engr., State Bldg., Civic Center, San Francisco 2.

Oct. 26-28—Ohio Section, at Deshler-Hilton Hotel, Columbus. Secretary, J. Howard Bass, Henry P. Thompson Co., 1720 Section Rd., Cincinnati.

Change in Date

Nov. 2-4 (instead of Oct. 19-21 as formerly scheduled)—Chesapeake Section, at Sheraton Park Hotel, Washington, D.C. Secretary, Carl J. Lauter, 6955—33rd St., N.W., Washington, D.C.

Nov. 9-11—North Carolina Section, at Robert E. Lee Hotel, Winston-Salem. Secretary, T. Z. Osborne, Asst. Director of Public Works, Greensboro.

Nov. 13-16—Florida Section, at Galt Ocean Mile Hotel, Fort Lauderdale. Secretary, John G. Simmons, Plant Supt., Water Dept., West Palm Beach.

Spring 1961

Feb. 1-3—Indiana Section, at Sheraton-Lincoln Hotel, Indianapolis. Secretary, Chester H. Canham, State Board of Health, 1330 W. Virginia St., Indianapolis.

Mar. 16—New England Section, at Statler-Hilton Hotel, Boston, Mass. Secretary, Ralph M. Soule, San. Engr., State Dept. of Public Health, Boston, Mass.

Mar. 22-24—Illinois Section, at LaSalle Hotel, Chicago. Secretary, Dewey W. Johnson, Research Engr., Cast Iron Pipe Research Assn., 3440 Prudential Plaza, Chicago 1.

Apr. 5-6—West Virginia Section, at Hotel Beckley, Beckley. Secretary, Hugh W. Hetzer, Design & Construction Dept., Union Carbide Chemicals Company, Box 8361, South Charleston.

Apr. 6-8—Montana Section, at Placer Hotel, Helena. Secretary, A. W. Clarkson, Asst. Director, Div. of Environmental Sanitation, State Board of Health, Helena.

(Continued on page 8)

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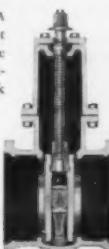


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WATERFORD
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Coming Meetings

(Continued from page 6)

Apr. 11-13—New York Section, at Statler-Hilton Hotel, Buffalo. Secretary, Kimball Blanchard, New York Branch Sales Office, Neptune Meter Co., 22-22 Jackson Ave., Long Island City 1.

Apr. 12-14—Kansas Section, at Baker Hotel, Hutchinson. Secretary, Harry W. Badley, Representative, Neptune Meter Co., 119 W. Cloud, Salina.

Apr. 14—California Section, at Biltmore Hotel, Santa Barbara. Secretary, Frank F. Watters, Hydr. Engr., State Public Utilities Com., State Bldg., Civic Center, San Francisco.

Apr. 19-21—Nebraska Section, at Cornhusker Hotel, Lincoln. Secretary, Joseph J. Rossbach, Metropolitan Utilities, 18th & Harney Sts., Omaha.

Apr. 20-22—Arizona Section, at San Marcus Hotel, Chandler. Secretary, A. D. Cox, Jr., Secy. & Comptroller, Arizona Water Co., Box 5347, Phoenix.

Apr. 23-26—Southeastern Section, at Poinsett Hotel, Greenville, S.C. Secretary, N. M. deJarnette, 96 Poplar St., N.W., Atlanta, Ga.

Apr. 26-29—Pacific Northwest Section, at Empress Hotel, Victoria, B.C. Secretary, Fred D. Jones, W. 2108 Maxwell Ave., Spokane, Wash.

Jun. 1-3—Canadian Section, at Prince Edward Hotel, Windsor, Ont. Secretary, A. E. Berry, 72 Grenville St., Toronto, Ont.

Jun. 20-22—Pennsylvania Section, at Galen Hall Hotel, Wernersville. Secretary, L. S. Morgan, 413 First National Bldg., Greensburg.

OTHER ORGANIZATIONS

Oct. 17-21—48th annual National Safety Congress, Chicago, Ill., with sessions on industrial safety scheduled for Conrad Hilton, Pick-Congress, Sheraton Towers, Morrison, and La Salle hotels. Write: R. L. Forney, Secy., National Safety Council, 425 N. Michigan Ave., Chicago 11, Ill.

Oct. 19-21—National Society of Professional Engineers, Statler-Hilton Hotel, Denver, Colo.

Oct. 25-27—ASA 11th National Conference on Standards, Sheraton-Atlantic Hotel, New York, N.Y.

Oct. 31-Nov. 4—APHA annual meeting, San Francisco, Calif.

Nov. 27-Dec. 2—Annual meeting, ASME, Statler Hilton Hotel, New York, N.Y.

Dec. 12-14—National Conference on Water Pollution, USPHS, Washington, D.C.

SHORT COURSES

Oct. 24-28—9th annual water works management short course, cosponsored by the Illinois and Indiana sections, AWWA, at Allerton Park, Monticello, Ill. Write: T. E. Larson, Head, Chemistry Sec., State Water Survey Div., Box 232, Urbana, Ill.

Nov. 7-11—Course on "Radioactive Pollutants in Water," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Nov. 14-18—Course on "Radionuclides in Water," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

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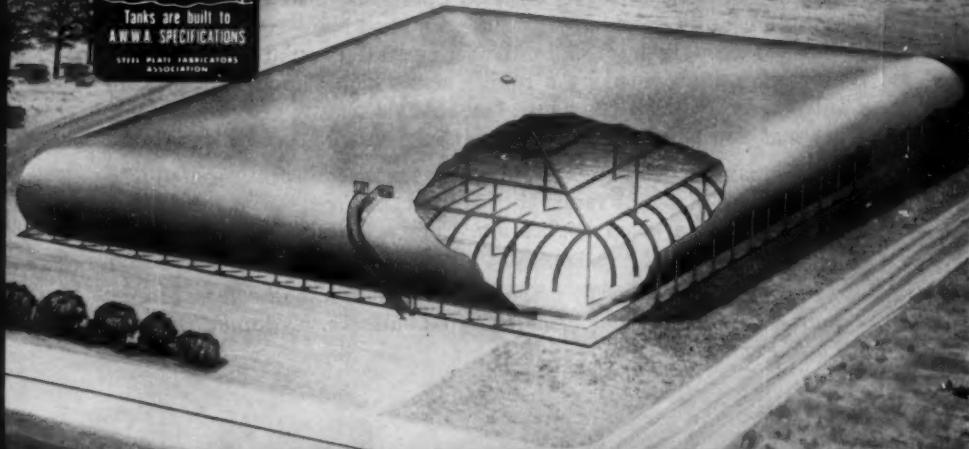
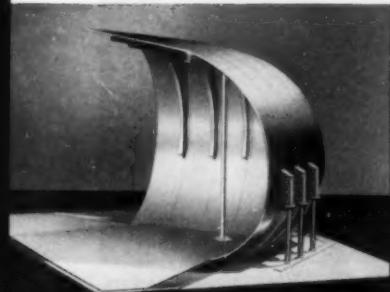
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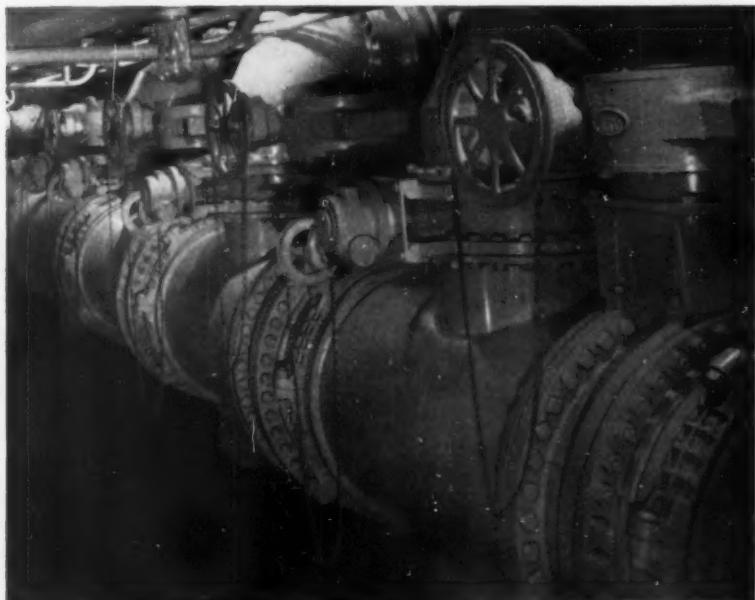
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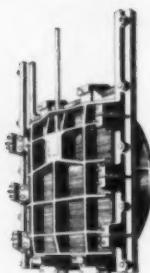
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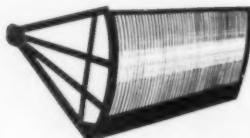
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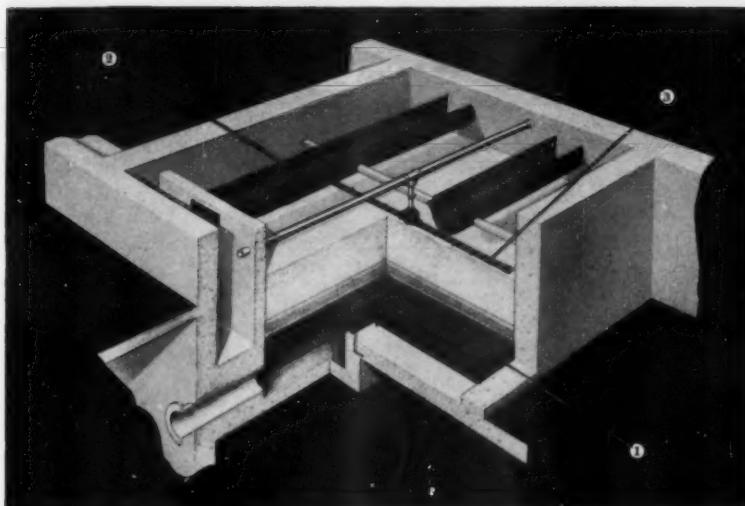
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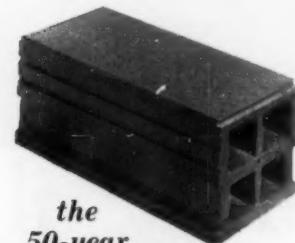
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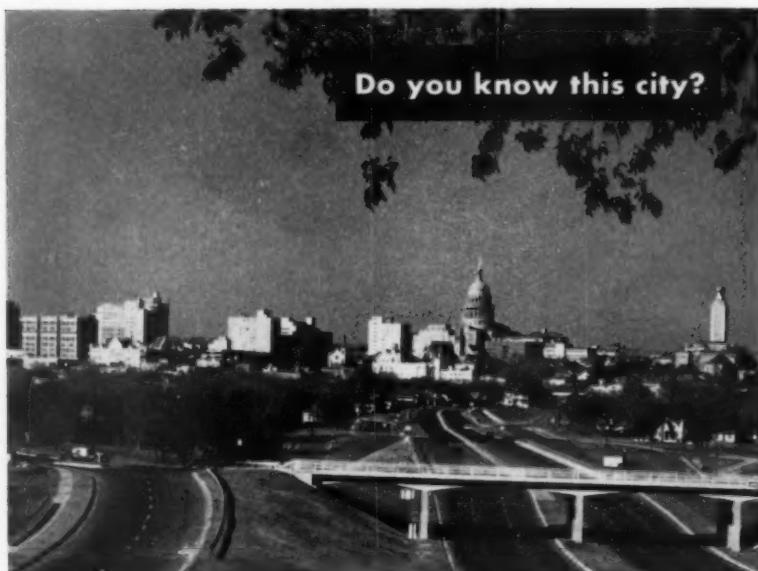
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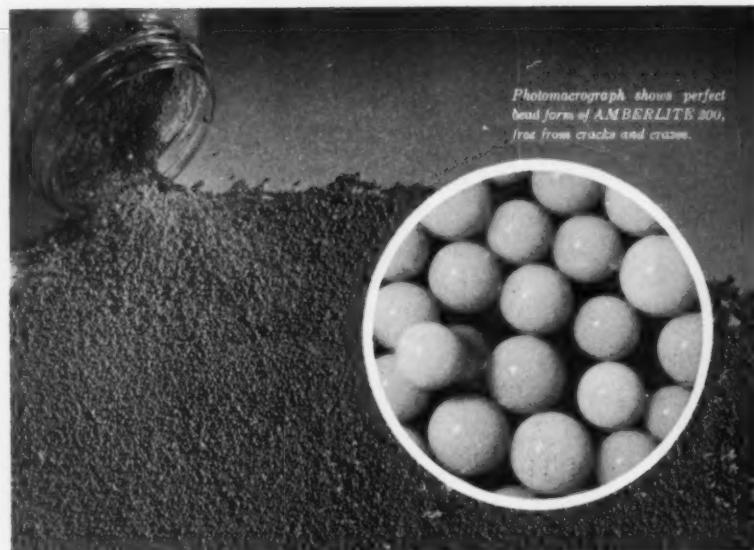
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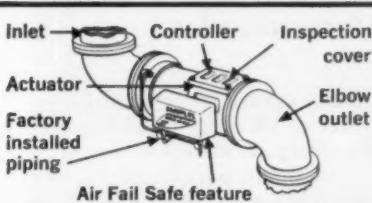
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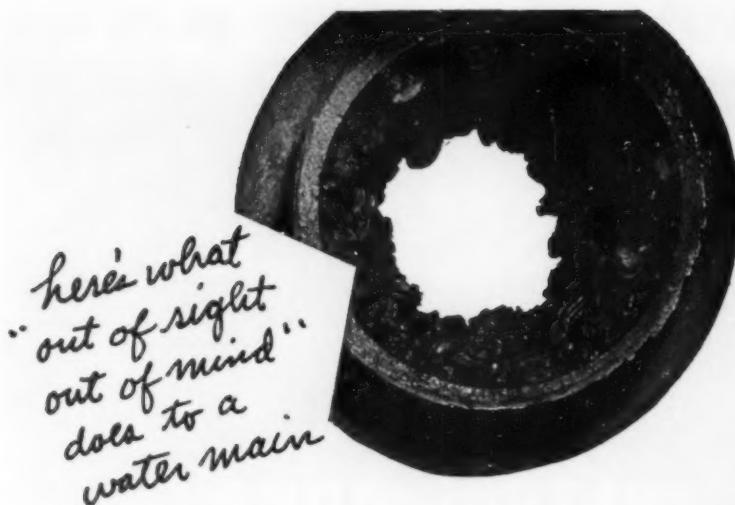
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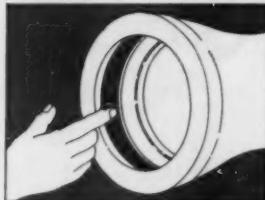
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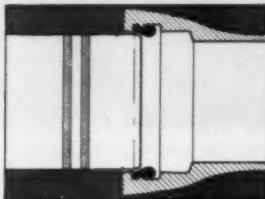
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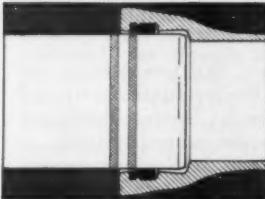
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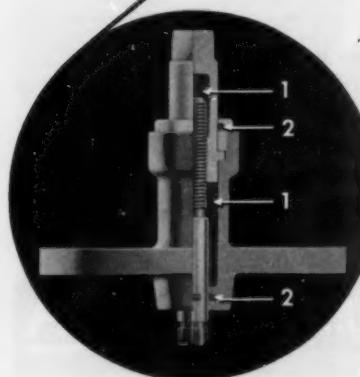
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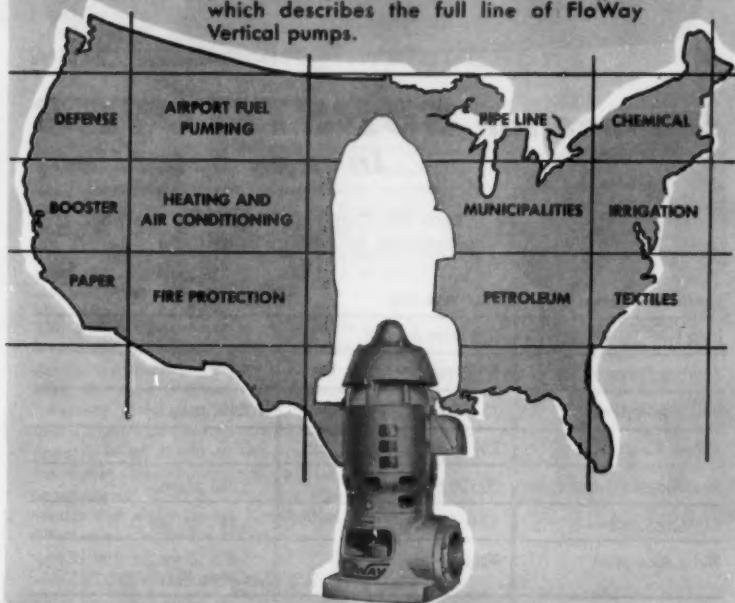
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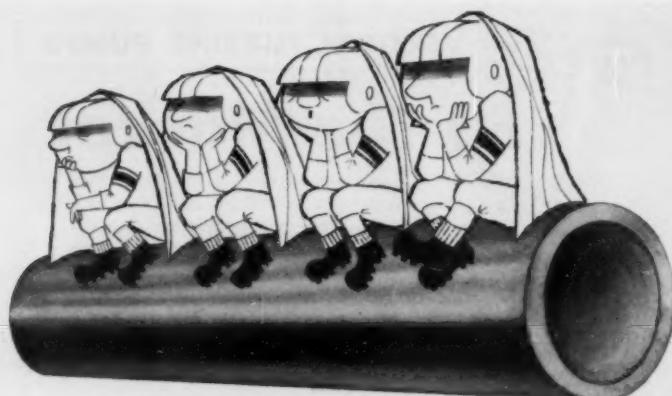
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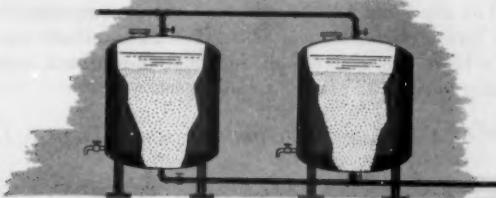
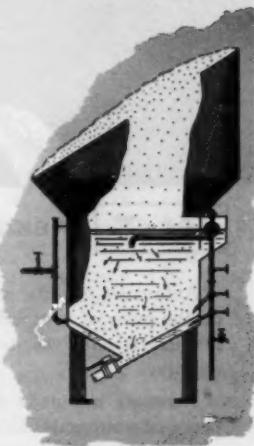
BRINE FILTRATION

How it can affect design of water softening installations

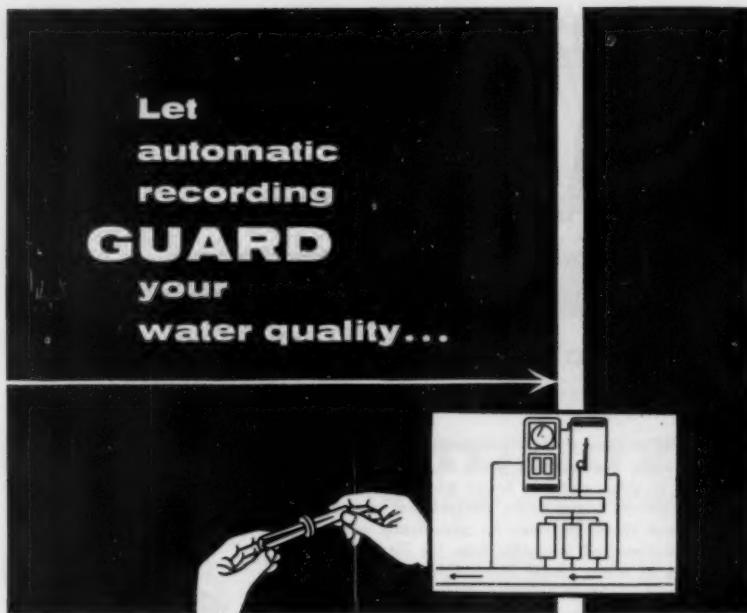
Whichever filter medium you select—sand, gravel or anthracite, undissolved crystals of rock salt—this much is clear: dissolver design and regeneration expenses are bound to be affected. For example: Provision should be made for periodically removing the accumulated insolubles from the filter bed. Design of filters should incorporate the necessary cleanout facilities. And a brine-filtration setup that performs well with one type of salt may be inadequate with another.

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Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 52 • OCTOBER 1960 • NO. 10

Principles of Rate Making for Publicly Owned Utilities

Samuel S. Baxter

A paper presented on May 17, 1960, at the Annual Conference, Bal Harbour, Fla., by Samuel S. Baxter, Water Comr. & Chief Engr., Philadelphia, Pa.

MUCH material on the subject of water rates has been published in the last 50 years. Some of it covers a broad field; some of it pertains to specific applications. Any listing of published works on this subject would be sure to omit valuable contributions, but at least three works merit discussion here:

1. A book on meter rates, by Allen Hazen¹
2. A joint report on rates and rate structures, by ASCE and the American Bar Association (ABA)²
3. An AWWA committee report on rate schedules.³

Actually, the subject of water rates is centuries old. The control of water was discussed as long ago as 97-100 AD by Frontinus,⁴ water commissioner of Rome.

Hazen's Book

Hazen's book¹ written in the comparatively early days of water meter-

ing, was founded on work done by Hazen when he was chairman of a committee of NEWWA. Published 42 years ago, the volume propounds the theory that the only logical and fair way of selling water is by measurement, and that this measurement should be done with water meters. Metering, of course, had been in use in the United States for about 40 years prior to the time that Hazen wrote his book. By 1900, quite a few medium-sized cities in the United States were 80 per cent metered or more. Most of these were in New England, although Atlanta, Ga., is included in the list. By 1917, the idea of charging for water by using meters had become the practice in many American cities. Hazen lists examples of meter rate structures in at least 70 cities throughout the United States. These were not all 100 per cent metered.

Although any generalization on the broad subject of rate making can be

unfair, Hazen reported on the method still used and understood by many. This method involves a service charge or a minimum charge, with or without a water allowance, and a step rate in three phases, in which the unit cost of additional water decreases as the quantity used increases. Hazen noted in 1917 that although early rate structures were designed to distribute costs fairly, many local conditions affected rates. Water plants were new in many localities, and everyone did not use water from the utility. An analogy is made from the earlier history of railroads, in which one railroad man is quoted as saying that "it was once policy to make operating expenses on everything it [the railroad] touched, and to make profits where profits could be made."

Hazen described the rate structure adopted by NEWWA, a two-charge rate that has had considerable use. This type of rate included a charge for supplying water, a charge for distributing water, and a service charge that comprised the cost of service pipe, metering, and billing. In earlier practice, much of the cost of distribution was combined with the so-called service charge and apportioned on the basis of meter size. This made up one of the two charges; the cost of supplying water was the other. There were many problems and inequities that faced the early rate makers.

Hazen also described a new three-charge rate. The terms that he quotes are still used today: *demand* was the capacity that the plant must meet; *output*, the amount of water pumped; and *consumer*, a factor related to the number of customers. In what was then a comparatively new procedure, there were recognized problems that

particularly involved the effect of the load factor.

ASCE-ABA Report

Another milestone in rate making resulted from the creation of a joint committee of ASCE and ABA. The committee was organized and began work in 1948; it published its joint report in the *Ohio State Law Journal* in the spring of 1951.² The committee also included representatives of several other organizations in the field, including AWWA. The work of the committee was undertaken because of the recognized need for a reexamination of the considerations affecting fair rates and rate structures of water utilities. The foreword to the report says that "with rare exceptions, rates and rate structures are fundamentally unsound." A fundamental principle was cited on which fair rates should be established:

The needed total annual revenue of a water works shall be contributed by users and nonusers (or by users and properties) for whose use, need, and benefit the facilities of the works are provided approximately in proportion to the cost providing the use and the benefit of the works.

This is, of course, a philosophy, and not a rate procedure.

It is important to consider the many different circumstances affecting rates, rate structures, and the application of various principles and philosophies in each state in the United States. Some of these circumstances directly involve the various laws, court opinions, and decisions of regulatory bodies. Others involve local practices, which, although they may have no specific background in law, are nevertheless well established and difficult to change.

As recently as 1951, the joint committee noted the absence of uniform practice in determining rates and rate structures and the scant consideration given to fundamental principles. It was aware that too often the plan adopted was one that would produce sufficient revenue with the fewest complaints. The committee also recognized the few plans that were fair to users and to property owners.

Many utilities were built before the costs of labor and materials became high, and for many water supplies the water rate paid only the operating and maintenance cost, with other forms of municipal financing paying the capital costs. The ASCE-ABA report listed the practices in use throughout the country when the report was published. The commodity charges for water included flat rates for unmetered customers, rates based on the value of property, uniform metered rates, and sliding-scale method rates. A second basic charge covered water for fire protection, but this varied greatly from city to city.

In order to conform to the fundamental principle mentioned before, the joint committee made specific recommendations regarding rate structures. A new thought expressed in the recommendations concerned the necessity for dual-rate structures, one rate for users and one for nonusers of facilities. The latter rate would require the nonusers to pay for some of the cost of the installation of water facilities before they are used.

The joint report devotes considerable space to an outlining of methods to be used in allocating costs between fire protection and general water service. It points out some of the methods and difficulties that are known to stu-

dents of this subject. In one method, the general water service cost is made an incremental cost by subtracting from the cost of the combined system the calculated cost of a system that would provide fire service only. Another method is to consider fire protection as an incremental cost by subtracting from the cost of the combined system the estimated cost of a system to provide general water service. Both of these were discarded as unrealistic and inequitable. The joint committee recommended and explained in detail the capacity-ratio method of determining fire cost. It suggested that a comparison be made between the costs of the maximum demand for fire protection and the maximum demand for general water use and the cost allocated on the ratio between these figures.

In recommending a procedure for the establishment of rates for general water service, the joint committee recognized the procedures outlined years earlier by Hazen and others which include a minimum or service charge and three or more steps of quantity rates. In developing this rate structure, the customer costs, among which are such items as general administration, meter reading, and billing, are included in the minimum charge. The actual cost of producing water is included in the quantity or commodity charge. The other basic charge, the capacity cost, which represents the plant maintained to meet all demands, causes much difficulty in a determination of how much of the capacity cost should be collected in the minimum charge and how much should be distributed among the various customers, with particular regard to the size of their meters and the amount of water used.

The committee, in noting that many water agencies determine capacity cost based on the maximum demand that the customer could place on the system—that is, the meter size—points out that no method existed at that time for measuring the maximum demand of each customer, with special regard to the hourly maximum or peak demand. The committee went further in suggesting that the capacity cost is affected by use as well as by demand. It recommended that this charge be divided equally between the various quantity charges on the one hand, and the minimum charges on the other.

The committee made a first step toward a real demand charge by recommending (the recommendation followed existing practice in some locations) that a major portion of the capacity charge be collected in the first block of the output or commodity rate. It pointed out also the need for a thorough consumer analysis of customer consumption as a means of determining how the various charges should be apportioned among the various users.

Faced with the same problem that others before and after it had faced, the committee recognized that a diminishing quantity of the fixed charges should be collected in the subsequent rate blocks, but noted that no fixed rules should be established for the division into the various blocks. It quoted with favor a report on water rates made by the Michigan Section of AWWA.⁶ The report stated that the first block would include a quantity of water equal to twice the average consumption through all $\frac{3}{4}$ -in. and $\frac{5}{8}$ -in. meters; the second block would include a quantity equal to twice the average consumption in 1-4-in. me-

ters; and the third block would include quantities in excess of the last amount.

The committee recognized special classes of customers—golf courses, summer residences, and seasonal users of air-conditioning equipment—that should pay the full capacity cost to meet seasonal demands. It pointed out the need for a satisfactory type of demand meter and suggested that in the absence of such a meter, special rates be established for special customers.

AWWA Reports

A most important contribution, which is now the manual on water rates,² is the AWWA committee report, "The Determination of Water Rates Schedules," presented in May 1953 at the AWWA Annual Conference and published in the March 1954 *JOURNAL*. In addition to a very thorough coverage of the subject, the report also has an excellent bibliography. The committee, headed by Louis Ayres of Ann Arbor, Mich., pointed out in the introduction to the report that the subject of water rates has been controversial for several decades and that it is not possible to resolve the controversy by any simple set of rules. The aim of the report was to point out the basic elements involved, including alternate procedures, and thus permit judgment to be exercised in meeting the local conditions and laws that were mentioned earlier in this article. The report should be read in detail by anyone who has a general interest in water rates and by those who are considering a revision of an old rate structure.

The committee suggested that all water utilities should receive a gross revenue to provide adequate service and insure the maintenance, development, and perpetuation of the system.

The report discussed the two principal classifications of revenue determination: (1) the utility basis, used by privately owned and operated companies and by public departments in the eight states that regulate agencies; and (2) the cash basis, generally used by publicly owned and operated utilities.

As this article is not concerned with privately owned utilities, the utility basis will not be discussed. It is merely noted that with the use of the utility basis, proper provision must be made for taxes, return to stockholders, and depreciation allowances. With the cash basis, such items are generally not required, although in some instances, payments are made in lieu of taxes, and a profit is made and allocated to other city funds and requirements.

The AWWA committee report discussed specifically the rates and charges for customers in suburban areas outside the limits of the municipality that owns and operates the water utility. It recommended that, inasmuch as the utility is owned by the citizens who operate it, users outside should pay not only the calculated charge but also the profit and other charges normally calculated on the utility basis. The report clearly outlined the three basic cost classifications in use in the United States for some time which are used in the demand basis method: (1) customer costs, which include such items as maintenance of service, maintenance of meters, meter reading, billing, and collection of accounts; (2) capacity costs, which arise out of providing plant and keeping it in readiness to serve; and (3) commodity costs, which vary directly with the amount of water produced.

The separation and allocation of capacity and commodity costs have been controversial for many years. The judgments or decisions made in allocating costs between the commodity and capacity classifications can cause decided variations in the actual rate charges. The committee pointed out that, for water utilities, a fairly high proportion of costs are in the capacity class, and that these costs are a substantial part of the total annual charges. In practice, a large portion of these charges is collected either in the minimum charge or in the first-step charge.

As early as 1925, the Water Works Practice Committee of AWWA⁵ considered this matter and recommended that the capacity charge should be limited to some reasonable amount and that the commodity charge should carry the major part of the entire cost of service. The Ayres committee report⁶ recommended the following definitions for the three classes of cost:

Customer costs: These costs shall comprise all operation and maintenance and fixed charges arising out of service to customers, including meters and services, collection and commercial expense, together with a suitable proportion of general and administrative expense.

Capacity costs: These costs shall be limited to a portion only of the fixed charges of depreciation, taxes, and return. After suitable deduction for fire protection, customers' investment, and property devoted to special uses, the remaining fixed charges shall be divided between the capacity costs and the commodity costs of normal users on a basis to be determined.

Commodity costs: These costs shall include all operation and maintenance expenses, except those chargeable to customers and to fire protection or other special services, plus a balance of the

fixed charges not allocated to capacity or customer costs.

The 1949 report* of the AWWA Michigan Section recommended an alternate method of functional distribution of costs. In this method, four major divisions are established: production, distribution, general customer service, and hydrants. Capital costs as well as the various charges for operation and maintenance are allocated to these four basic divisions.

The Ayres committee report discussed a problem that has become even more important than it was when the report was first written. It involves the allocation of expense between water users and taxpayers, and between normal water users and special users. On the one hand, the supplying of water can be considered equivalent to the supplying of any other commodity—food, electric service, or other necessary items—and the charges can be made in proportion to use and readiness to serve. On the other hand, water service does improve property values, contributes to fire protection, and safeguards public health.

In most water rate structures, fire protection charges can be calculated in some manner, and allowance is often made for such costs to be chargeable to the general taxpayers. The Ayres committee described in detail some definite methods and principles involved in the allocation of fire costs. There is no doubt that the cost allocated to fire protection varies greatly with the method of allocation used and with the size of the community. The ASCE-ABA committee noted that, although the principle of charging for fire protection is recognized, most municipally owned utilities do not make such a charge and that the

charge made by privately owned utilities is often nominal. It pointed out that the two reasons for this are a feeling that the method of computation has overemphasized the cost of fire service and that a fire charge would add more to the already overloaded general tax budget.

The other items of safeguarding public health and improving property values are much more difficult to ascertain in terms of cost. In past years, some of these costs were charged against the general taxpayer by having bonds for improvements paid from general taxes, not from water revenues. In recent years, more and more municipal operations have been financed by revenue bonds chargeable against water rates, or provisions have been made that water departments be completely self-sustaining in their financial operations.

Some use has been made of a charge against property to finance the cost of providing water service to a rapidly developing district or to provide a community with a distant source of supply. Such a charge is the result of an improvement and can thus be classified as an asset to property itself, rather than as a general contribution made by taxpayers. Perhaps the matter narrows down to two policies: one requiring that publicly owned supplies be completely financed from water revenues, and the other requiring or permitting some financial support to the water system from the general taxes. The Ayres report notes that most of the presently established water systems need little or no financial assistance from taxes, and that it might be unrealistic to have general property taxes help pay for utility services, in view of the already critical situation that exists in general property funds.

As does the joint ASCE-ABA report, the Ayres report noted that there appears to be an increasing number of special uses for water where maximum demand is higher than normal. Among the examples cited are fire protection, air conditioning, refrigeration, lawn sprinkling, and golf courses. The Ayres report suggests that a fixed charge should be allocated to such special uses in the form of a demand rate or other similar charge.

In determining rate schedules for normal use on the demand basis, some assumptions must be made. The Ayres report suggested that the total of demand cost should be limited to 50 per cent, chargeable to capacity, and the balance of the capital cost should be charged to commodity. It suggests that the 50-50 division would be justified in the common situation where the average daytime delivery rate on the maximum-demand day is approximately twice the average annual rate. Substantial departures from this might require some modification of the 50-50 division.

The Ayres report cited a real problem in equitable distribution of demand costs between the various classes of users. It is in this regard that the judgment factor used in distributing costs may make the demand charge heavier on certain classes of consumers. As in all recent discussions and reports, the committee pointed out that the development and use of a demand meter would solve this particular problem.

Other Reports

S. T. Anderson,⁷ formerly utilities director of the Department of Water, Light & Power of Springfield, Ill., made some interesting comments concerning rates of municipally owned

utilities. His opening comment might well set the tone for this article:

There is always a difference of opinion about the proper procedure for setting up water rates. It is doubtful whether any two experts can agree on a method to be used or on the factors that should be taken into account.

Another point made by Anderson is that because municipal rates are generally subject to approval by a city council, which is reluctant to increase rates for fear of the adverse effects on the chances of reelection of its members, management must not only prove to the council that rates are justified but must also convince the public that the rates are reasonable and necessary.

W. J. MacIntosh,⁸ in discussing rate structures for water utilities in Pennsylvania, made an interesting observation. Although publicly owned utilities, he says, can assess the cost of certain capital additions against property, regardless of whether or not immediate use is made of the service, privately owned utilities do not have this same privilege.

Current Problems

W. D. Hurst, city engineer of Winnipeg, Man., in a private communication to the author, pointed out several controversial matters regarding rates which will be discussed here. Some of them have presented problems for many years; the importance of others has been of more recent origin.

Demand meters. Although it is doubtful that demand meters as such were seriously considered 40 years ago, it is interesting that Hazen¹ recognized the load factor as being of some importance in determining rates. In recent years, the question of fixing a rate schedule to meet high peak loads

that last for only a short time or for a short period of the year has become of real importance. This is especially so with regard to air-conditioning equipment, which uses large amounts of water for a few months only. It is possible to make some determination of a demand rate based on the size of the air-conditioning equipment.

Although special demand rates, some of which have been attacked in the courts, have been established in some communities, there has not been widespread use of demand meters. Most of these rates have been based on the size of equipment. In more recent years, the need for demand meters has become so great that a panel discussion⁹ was presented at the 1959 Annual Conference of AWWA, with comments made by managers of utilities, engineers, and meter manufacturers. In his remarks at the panel discussion, G. H. Dann, of the Philadelphia Suburban Water Co., pointed out that air conditioning was not the only service that placed a heavy peak load on his system, but that golf courses, private swimming pools, lawn sprinklers, and even schools and hospitals were included. Dann suggested that the real answer to the problem was the development of a demand meter, the education of the public as to why demand rates should be established, and the application of a special rate based on the cost of facilities provided to meet the daily or seasonal peak demands. Meters that provide the necessary data for demand billing are available, and some are in use. At the present time, those that are in use and those that are being developed are primarily for customers who use large quantities of water.

It would certainly seem that, inasmuch as normal users are helping to

subsidize those with poor load factors, and as the number of customers with poor load factors is comparatively small, a program of public education should at some time win public acceptance of the demand rate. The demand meter will certainly do the job required as soon as its development permits it to be bought at a reasonable cost. The use of empirical formulas based on the use factor can also be considered as a substitute for the demand meter.

Equitable assessment. Another problem concerns the equitable assessment of charges by cities to surrounding municipalities whose supply is purchased in bulk at the boundary line. There has been a considerable amount of experience with this problem, because the expansion of suburban communities has been made possible in many instances only by the water furnished from the central municipality. Several theories have been advanced, but the one that seems most appealing is based on the fact that the water utility is owned by the citizens in the central municipality. Use of these facilities by those who do not own it should result in a fair rate of return on that portion of the facilities involved. It is certainly possible, even for the most complicated water systems, to segregate the capital cost and to apportion the operating and maintenance cost of those facilities that serve an outside area. Then an equitable charge can be made for all of these costs, including a reasonable return or profit.

Where the service outside the city is small in comparison with the total service furnished by the city, such calculations may be difficult, costly, and not worth the time involved. In these instances, a broad, overall examination can be made of the entire cost of the

system, the charges and profit prorated, and a fixed percentage added to the regular bills. One of the difficulties in this procedure is that many publicly owned utilities do not have an accurate determination of their original cost or replacement cost. Another problem is that such rates may have to be determined by rules promulgated by the public utility commission of the state.

Fire protection. A rational approach is needed to charges for fire protection in large utilities for which fire demand is a minor factor in the design of the system. The three published works¹⁻³ referred to earlier, and the references contained in them, discuss this problem. All the methods mentioned have some justification or merit when applied to specific instances. Any method used under specific circumstances by one expert can easily be challenged by another expert.

Of special interest to publicly owned utilities is the relationship between the utility and the governmental agency that pays for fire protection. In many instances, the utility is a department or other subdivision of the same municipality that must pay the fire cost from its general tax budget. When this is true, the rate maker must face the fact that the rate he charges for fire protection must be accepted by the governing body of the municipality. In view of the stringent position in which most municipalities find themselves with regard to their general fund, there is apt to be resistance to payments for fire charges, if they do not already exist. By the same token, there will also be resistance to increasing any existing cost.

The author can cite his own experience in this matter when he established a hydrant rate in Philadelphia for the

first time 8 years ago. In the absence of accurate cost figures at that time, a rate of \$20 per year was established. This was done with the hope, which was realized, that such a payment would be made from the general fund. Now that it is established, however, the chances of increasing it, no matter how erudite a theory may be used, are very slight. One way of solving the problem of fire protection costs is to select a rational method that will be accepted by those who must pay the costs.

S. T. Anderson⁷ stated that 65 per cent of the cost of water is chargeable to fire protection. These figures are probably based on his experience in Springfield, Ill., a city of approximately 100,000 people. The wide variation in thought on this matter is shown by the fact that the \$20 hydrant charge in Philadelphia represents only about 3.5 per cent of the water revenue. Although this charge is low, it is noted that a \$60 hydrant charge would represent only about 10 per cent of the water revenue. It is obvious, as has been pointed out in earlier articles, that the size of the city and type of water use has much to do with any rational calculation of fire costs. The author knows of no easy solution or ready-made formula for establishing fire costs.

Service charge. A difference of opinion exists on whether there should be a service charge plus commodity rates or minimum billing with no service charge. The practice varies considerably in the use of minimum charges, service charges, the items that are included in these two charges, and the amount of water permitted to be used with a minimum charge. It would seem that this is a subject that needs both judgment and a considera-

tion of local practice and conditions. The two terms *minimum charge* and *service charge* are sometimes loosely used, and they often have the same meaning. For the purpose of this discussion, service charge is a fixed charge without any allowance for water; minimum charge is an amount that includes both a fixed charge and some water allowances, regardless of whether or not such water is used.

The actual and direct business costs of metering, billing, service pipe, and some parts of administration remain the same regardless of the amount of water used. The service charge or minimum charge must include these items. There must also be some way of making sure that some of the capacity costs are paid on a regular or fixed basis. These, again, should be included in the service or minimum charge.

Beyond this point, the consideration of whether some water allowance should be permitted and added to a minimum charge is one that requires judgment and an evaluation of local practice. If the minimum is fixed high enough so that a substantial number of customers do not exceed the minimum, there is either some additional cushion in the revenue or an allowance can be made for this amount in the general rate structure. It is interesting to recall that one of the original reasons for including some water allowance in the minimum bill was the desire to induce consumers not to economize and use less water than was supposed to be necessary for their health.

The author's own choice of policy would be to have a service charge that would definitely cover enough of the fixed charges to make the rate structure both sound and equitable and to

charge for all water used at the commodity rate. Local custom, however, can make such a choice difficult, as was shown by the author's experience in Philadelphia. Prior to 1948, the annual allowance for residential customers was 60,000 gal, which was included in a minimum bill. In 1948, the allowance was reduced to 30,000 gal a year. This allowance was opposed considerably by citizen and political groups, some of which oppose it to this day. Attempts to eliminate the present allowance or to reduce it, have been met with countersuggestions to change it back to the original 60,000 gal. This desire to permit the use of a certain amount of water without the amount being a factor in the bill is interesting, in view of the fact that about 14 per cent of the customers do not use the present annual allowance of 30,000 gal.

Special rates. Special water rates to cover such uses as for air conditioning and lawn sprinkling are another controversial matter. A general review of the literature and discussions with water utility operators seem to indicate a general acceptance of the fact that the poor-load users of water for special purposes should pay their fair share of the cost of supplying this service through special rates. It has probably been the layman's belief that water is supplied in some magic or automatic way which has led him to think that there are no special problems in meeting these extreme peak loads. The sooner that governing bodies, regulating bodies, and all classes of users recognize that the ordinary user is subsidizing unfairly the poor-load user, the quicker will there be an acceptance of special rates.

Special rates have been established by the use of different methods of determining the load factor and its cost.

Further determination of acceptable methods, including the use of demand meters, should be of help. Although there are a number of examples to illustrate this problem, Detroit's data are of particular interest. In Detroit, a study has shown that the rate structure is equitable for all service provided when the peak hour usage does not exceed the average annual usage by a ratio of 7 to 1. It was also found that the air-conditioning ratio showed a maximum hourly use over average use of approximately 17 to 1. Therefore, an extra demand charge of \$7.50 per ton per hour was established on nonconserving air-conditioning equipment. At present, however, this peak rate is being contested in court.

Block rate. Other problems on which there are differences of opinion are the establishment of block rate structures to recoup commodity costs and the justification for a fixed ratio between these steps. The block rate has been in existence for quite some time. The form of rate adopted by NEWWA in 1916 had three different steps above the service charge for which the terms *domestic rate*, *intermediate rate*, and *manufacturing rate* were used. As a guide, it was suggested that the manufacturing rate, which was the lowest, should not be less than half the domestic rate, and that the intermediate rate should be approximately between the two.

Hazen¹ noted that earlier rate structures had used the ratio of 3 to 1 and higher between the rates charged the smallest customers and those charged the largest customers. He points out that the conditions which warranted such a scale had disappeared by 1918, and that a ratio ranging between 1.5 and 2.0 to 1 is all that is justified between the highest and lowest steps.

The Ayres committee report,² in discussing the demand basis for commodity rates, cites the earlier AWWA report of 1923,¹⁰ which suggests three or four slides or steps. This report indicated that the ratio between the first and third steps should not be more than 2 to 1, and that the ratio between the first and fourth steps should not exceed 3 to 1. The fourth step would be for very high usage.

The Michigan Section report in 1949⁶ suggested another method of establishing the relationship between the three steps. With this method, the wholesale or manufacturing rate is obtained by dividing the total cost of all production and transmission expenses by total annual sales of water. The intermediate rate is obtained by adding an increment to the wholesale rate, an increment found by dividing the total cost for distribution mains larger than 6 in. by the water sold through all meters, after deducting the sales at the wholesale rate. The domestic rate is obtained by adding an increment to the intermediate rate, an increment found by dividing the total cost for a main 6 in. or smaller by the water sold through all small domestic meters. The use of this method requires the judgment mentioned before. There certainly can be no exact mathematical formula that can be justified to the exclusion of others. As long as some reasonable limitation is kept between the three steps, and as long as a substantial part of the capacity cost is kept in the first step, it would seem that a ratio could be established for any community and maintained through several rate changes.

Recent Rate Studies

Some excellent rate studies have been made in the last several years.

Notable among these are the studies made in Dallas, in 1959, and in Denver, in 1958. These very thorough reports apply many of the factors discussed in this article. Each case involved a comprehensive study and analysis of existing and proposed costs and an application of these costs to the various classes of uses and customers. Judgment factors were used, and certain local factors and conditions that had to be maintained were recognized. These two official reports have not been published and are not generally available to the profession.

Both of these rate studies involved the calculation of rates for water supplied outside the main city. The Dallas study has a special point of interest, which, although it may be limited in its application to other cities, points out a trend toward the joint operation of water and sewage facilities. In Dallas, where the lawn-sprinkling load is of importance, separate meters had been installed for regular measurements of water used for lawn sprinkling. A higher rate was charged for the use of these meters, but a sewer charge was not included. The new rate structure, by a judicious use of a combined water and sewer rate on the one hand, and a higher separate lawn-sprinkling rate on the other, has attempted to reduce the actual number of double services. Recognizing the same competitive factors that faced railroads, which were referred to earlier, Dallas has also given consideration to rates for industrial water, rates that will make it possible for Dallas to compete with other cities in the location of new industrial plants.

The demand rate has recently been put into effect in San Francisco, where the central utility sells water in bulk to some outlying customers. Some of

these customers have sources of their own and use San Francisco water only to meet peak demands for a brief period during the year. New rate schedules provide a demand charge, with a provision that this charge shall not be less than 75 per cent of the highest demand charge made in any one of the preceding 11 months. Because the water rate in the block involved is 15 cents, and the demand charge is 1 cent, as compared to the former straight charge of 16 cents, it can be seen that customers using water with some regularity will be affected little or not at all, and that only those who have a peak demand for a short time will be required to pay an additional amount.

Conclusions

W. V. Weir, quoting from L. R. Nash's book, *Public Utility Rate Structures*, published about 60 years ago, said: "The successful builder of rate structures must be primarily a philosopher rather than a technician."¹¹ Although Weir's article and many others have pointed out the need for judgment factors in rate making, it is nevertheless a fact that techniques and conditions have been greatly developed in the last 60 years, and it now takes much more than a philosopher to establish an equitable rate structure. There is a wide gap between the procedure that works entirely on theories and mathematical formulas in devising a new rate structure and the other procedure that chooses any new rate structure that arouses the least amount of public antagonism. It is, of course, obvious that when the establishment of rate structures is discussed in the water utility field these days, what is really being talked about is an increase in the present rate structure.

There seems a very definite need for rate structures to be founded on a complete analysis of customer usage, demands, and costs. It ought not to be necessary to remind those in publicly owned utilities to have a complete system of utility accounts, but it is a fact that many do not. Without the complete data that such a system of accounts makes possible, no rate structure will have a very firm foundation. A fair and equitable division of costs among all classes of customers certainly requires that something be known about the use and demand that these customers place on the system. Although the analysis of use and demand by various classes of customers is admittedly difficult and perhaps costly, it is an important factor on which an equitable rate structure should be based.

Rates in publicly owned water utilities should remain constant for a period of years, despite the ever increasing costs and expanding population in many communities. Whether the rate should be constant for 3 years, 5 years, or for even a longer period is a matter for local decision makers who account for local conditions. Inherent in a method for stabilization of rates, however, in view of rising costs and increasing expansion, should be the ability of the publicly owned utility to accumulate reserves in the first years of the new rates in order to offset increased costs in later years. The accumulation of these reserves is often subject to laws and, where laws do not exist, to other conditions, or to an effort to divert these funds to other purposes.

The minimum or service charge should certainly include enough of the fixed charges of the utility to make sure that the system remains solvent

under adverse economic conditions. The charge should also be distributed in such a way that the various classes of customers pay their fair share. As noted earlier, the actual cost of all water should be included in the commodity rate, but the determination of whether some water should be allowed in the minimum rate is a decision to be made by each community. The customer who uses a large amount of water for a very short time is certainly responsible for extra charges placed on the system. The demand rate is a fair way to account for these charges, and regardless of how the actual measurement is made, the demand rate can be adjusted according to the conditions involved and by the type of meter used.

Services rendered to customers who do not own the water system should be made at rates higher than those for the owners. In addition to the costs involved, the users outside the boundaries of the central system should pay an amount that in some way approximates a reasonable return or profit on the facilities used.

The ultimate goal for publicly owned utilities, as for privately owned utilities, is to become completely self-sustaining. In practice, however, the meaning of the term "self-sustaining" is found to vary considerably. Many systems that pay all operating costs and capital costs, and that make a complete accounting between the water fund and the general fund for services rendered to or by the water utility, do not pay local taxes or even some lesser amount in lieu of taxes. On the other hand, it is often found that water service is furnished to the municipal government at little or no cost, that fire protection costs are nonexistent or far too small, and that some

other cost, like that for fluoridation, is charged to water users rather than to the public health budget. It will be the unusual case when all of these costs and others are completely accounted for in the rate structure, but progress should be made step by step.

Although public opinion is not a factor that can be added to a rate structure as a mathematical figure, it is important. Every effort should be made to keep the public informed on the need for proper rates for water and on the equitable division of these rates. The rate maker today has a wide choice of methods for devising a rate structure and must exercise his judgment in many instances. The consequent variety of the methods and principles he can use to establish rates makes it possible for critics to discredit the method chosen.

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Demand Rates and Metering Equipment at Milwaukee

Arthur Rynders

A paper presented on Mar. 16, 1960, at the Illinois Section Meeting, Chicago, Ill., by Arthur Rynders, Supt., Water Dept., Milwaukee, Wis.

DEMAND rates are charges that take into account the customers' demands for water. Customers' peak demands that are nearly concurrent with the utilities' peak load are the most significant. The higher a customer's peak demand, the higher the charge; conversely, the more nearly uniform the rate of withdrawal of water from the utility system, the lower the charge.

The reasoning behind demand rates is that the customer who has a peak demand concurrent with the utility's peak load should pay for the extra system capacity required to supply the amount that his peak demand exceeded his average demand. The customer should pay for the extra capacity because it is required to serve him for a relatively short time. A demand rate is designed to recapture the cost of this extra capacity. Moreover, a demand rate may motivate the customer to investigate the means of moderating his demands. In some instances, he will find that he can save money by moderating his demands; in other instances, he will find that it is more economical for him to continue to have the utility provide his requirements. Another advantage of demand rates is that the utility can more fairly distribute the cost of water service among its customers.

Past Experience

The establishment of, and experiences with, demand rates for the Milwaukee system are good examples of the problems involved with these rates. Over a period of years, the utility had acquired a large amount of information about the peak rates of flow to several suburbs. These peak rates were discussed with the Wisconsin Public Service Commission when commensurate rates were requested. The suburbs were not pleased with the utility's request, and thus the existing dissension over rates was intensified.

A new approach to the problem in the form of a demand rate was proposed. On the basis of Milwaukee's own experience, the experience with demand meters in Kansas City, Mo., and the presentation of Milwaukee's engineering staff and staff of consulting engineers, the public service commission granted the city a new water rate. This rate took into account the peak rate of flow drawn from the utility system by the customer. Essentially, the rate has two parts: (1) a commodity charge and (2) an extracapacity charge. The commodity charge, 7.5 cents, is for each 100 cu ft of water used during the month. The monthly extracapacity charge, \$4.50, is for each 100 cu ft of water taken per hour in excess of the average annual

TABLE 1
Demand Rate Experience *

Customer	1938		1939	
	Avg. Ratio %	Avg. Rate cents/ 100 cu ft	Avg. Ratio %	Avg. Rate cents/ 100 cu ft
A	121.7	9.13	125.4	9.38
B	119.4	8.96	119.3	8.95
C	117.2	8.78	118.4	8.88
D	114.5	8.59	113.3	8.50
E	118.6	8.90	102.0	7.65

* Commodity rate, 7.5 cents per 100 cu ft.

hourly amount used during the current and preceding 11 months.

The demand rate almost solved the problem. The water department continued to determine peak rates with the portable recording-type meters* that had been used in earlier studies. The first noteworthy incident was caused by Customer E (Table 1). During the testing of a pumping installation, the customer's peak rate of demand, in terms of extracapacity charges, really caused him to be concerned. Because the water that customer purchased from the utility was dumped into underground storage tanks and repumped into his system, he discovered that he could regulate the flow from the city system to his underground tank and effect a considerable reduction in water bills. Accordingly, he purchased a regulating valve and has since operated at a nearly uniform rate of withdrawal.

Equipment

The expense of owning, operating, and maintaining suitable demand meters required the utility's attention. The portable recording-type meters that had been used were satisfactory

* Pitometers, made by The Pitometer Assocs., New York, N.Y.

for research but were not suited for continuous metering for billing purposes. The service conditions under which a meter for regular service had to operate were unusual, in that the recording mechanism would be housed all year in an unheated cabinet placed outdoors. The recorder would be expected to operate unattended for 30 days or more and to total the flow through each of the several meters serving one customer. The recordings should be understandable to the customer, as well as to the utility. The service conditions appeared to be met by one combination of metering equipment, but operating experience in the proposed service was lacking. In order that all concerned might be satisfied in the matter of operating experience, one meter of the combination



Fig. 1. Recording End of Demand Meter

The clock in the center of the instrument can be set for various demand periods.

type was purchased, installed, and operated under service conditions for several months. In the meantime, discussions were held with the suburbs and the public service commission to establish whether the utility or the customer would pay the expense of the meters. This was resolved by the public service commission's decision that the customer would pay the expense. In negotiations with customers, it was determined that they preferred to rent rather than purchase the meters. Accordingly, the customers signed rental agreements, whereby the utility was to furnish, install, and maintain the meters.

Figure 1 shows the recording end* of the demand meter purchased and operated on a trial basis since February 1959. To date, this meter has performed perfectly. The disc in the approximate center of the instrument is a clock that can be set for various demand periods. The punched tape at the right of the instrument summarizes the registration of flow. The transmitting end† of the demand meter is shown in Fig. 2. The mounting of the energized pulse generator on the meter is clearly shown. A T-shaped gear box is used to maintain the original gear ratio for the meter register, on the left, and allow a ratio change for the pulse generator, on the right.

The recording equipment for all the meters on a customer's supply is shown in Fig. 3. The equipment is mounted on a panel installed in a weatherproof housing near one of the meter pits.

* Digital Demand Recorder, made by Fischer & Porter Co., Hatboro, Pa.

† Made by Badger Meter Mfg. Co., Milwaukee, Wis.

On the recording tape at the right of the clock is punched the summarized registration of flow, for each 15-min interval, for all of the meters supplying the customer. The lower cabinet houses the remote-type register of each meter supplying the customer and the relays required for totalizing the pulses of all the pulse generators attached to the several meters.

In 1958, Customer A's average ratio (Table 1) was 121.7 per cent. This ratio was determined by averaging the

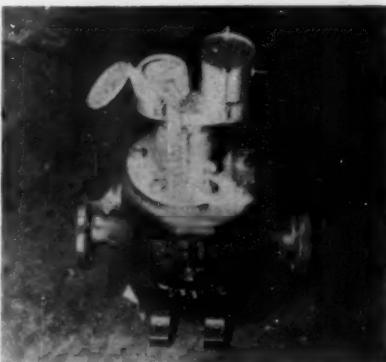


Fig. 2. Transmitting End of Demand Meter

The T-shaped gear box is used to maintain the original gear ratio for the meter register, on the left, and allow a ratio change for the pulse generator, on the right.

ratio calculated each month by means of the public service commission's formula. The average rate charged for water used by Customer A during 1958 was 9.13 cents per 100 cu ft. This amounted to a premium of 1.63 cents per 100 cu ft more than the commodity charge. Ratios and rates are shown for five customers for the years 1958 and 1959. Attention is called to

Customer E, mentioned before. He saved about \$8,000 by installing a regulating valve.

Table 2 shows the estimated costs and quarterly rental charges of demand meters for four customers. The use of existing meters, meter pits, and the type of meter mentioned earlier proved to be the most reliable and economical means of providing demand

that use water without conserving devices. The reasoning behind a demand rate in this instance is the same as that previously mentioned—that is, the customers' peak demands are nearly concurrent with the utilities' peak load. The approach, however, has been somewhat different, in that most of the customers could install water-conserving devices and, by so doing, obviate the expense of installing a demand meter. The simpler and less costly means of arriving at an extra-capacity charge was based on the total tonnage of nonconserved air conditioning each customer might use. Some of the customers, however, have continuously objected to a demand charge on air conditioning.

The public service commission, in granting increased rates to the Milwaukee utility on May 10, 1957, retained jurisdiction over a proposed schedule applicable to water-cooled air-conditioning systems. Additional hearings were held on Jul. 29, 1957, and on Sep. 9, 1957. An order dated Feb. 17, 1958, issued by the commission, established an annual surcharge on installations placed in service after the date of the order and on all existing installations beginning with the 1959 season. The commission's order set the surcharge at \$10 per ton for each customer's total tonnage in excess of the first 3 tons. Confirmation of the commission's order by the common council was deferred, and a report on all varieties of seasonal water consumption was requested. Such a report was compiled for the water department by a firm of consulting engineers.* The report explored the feasibility of a surcharge for users of large quantities of water whose summer

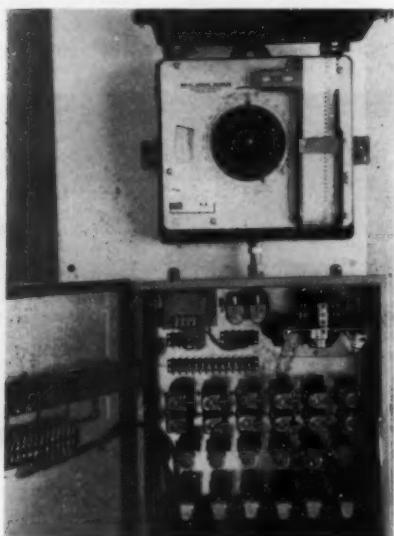


Fig. 3. Recording Equipment for Several Demand Meters

The equipment is mounted on a panel installed in a weatherproof housing near one of the meter pits.

meterings. For the years 1958 and 1959, the total annual bills to these customers ranged from \$35,000 to \$300,000.

Rates on Air Conditioning

Another type of demand rate that has been a problem for years relates to customers' air-conditioning systems

* Black & Veatch, Kansas City, Mo.

TABLE 2
*Estimated Cost and Quarterly Rentals
 of Demand Meters*

Customer	No. of Meters	Total Estimated Cost of Meters Installed \$	Quarterly Rental \$
A	4	3,600	115
B	3	2,400	75
C	2	2,200	70
D	4	4,700	150

* Including depreciation, maintenance, power, and supplies.

quarterly bills exceed the average use during the previous three quarters. The report stated that "it is both common practice and equitable to charge separately for water used by nonconserving air-conditioning equipment."

On Jul. 28, 1958, the commission wrote to the water superintendent regarding the failure to apply the rates ordered and referred to state statutes covering penalties for this violation. Several substitute ordinances regarding air conditioning were next considered by the utilities committee of the common council; none of the ordinances was passed. About this time, a group of customers using nonconserving air-conditioning installations appealed to the circuit court for restraint of the order. After more hearings, the common council passed another resolution consenting to the remanding of the order from the circuit court to the public service commission and essentially preconfirming any order the commission might issue.

Recently, the commission held more hearings and now has the matter under advisement.*

Future Prospects

It is anticipated that demand rates will be used more in the future than they are at present. The practice of water utilities is far behind that of other utilities in the field of demand metering and demand rates. Probably the principal reason for this situation regards the availability and cost of suitable demand meters for water service. Only for customers using very large quantities of water can demand meters be justified at today's costs. If and when suitable demand-metering equipment can be produced at a lower cost, its use will increase accordingly. In the meantime, two means of utilizing demand rates may be considered: (1) demand meters for customers using very large quantities of water and having high peak demands; and (2) a simpler, less costly, although approximate means of determining the customer's peak demand—a surcharge on tonnage of nonconserving air conditioning.

* On Mar. 29, 1960, the Wisconsin Public Service Commission issued a supplemental order pertaining to nonconserving water-cooled air conditioning and refrigeration. This order had the result of placing a demand charge into effect for the 1960 season. On May 12, 1960, the commission issued another supplemental order clarifying the previous one. The Milwaukee utility is proceeding with surveys for billing and will bill nonconserving air-conditioning systems during the current year.—Ed.

Concrete Pressure Pipe in Today's Water Industry

Ernest W. Whitlock

A paper presented on May 18, 1960, at the Annual Conference, Bal Harbour, Fla., by Ernest W. Whitlock, Partner, Malcolm Pirnie Engrs., New York, N.Y.

CONCRETE pipe has been used for carrying potable water for many centuries, but the past 30 years have witnessed a great increase in its use by the water industry, and a number of new types have been developed. Some of the newer types are in general use throughout the United States and in many other parts of the world; other types are in use only in certain localities.

Historical Development

The Romans constructed many concrete water lines. Some of these remained in service for many centuries. In the United States, concrete pressure pipe first was used more than 100 years ago in the West to carry water for irrigation.

From 1870 to 1900, a kind of concrete pressure pipe was developed and used to a considerable extent in New England. It consisted of a sheet of wrought iron, lapped and riveted to form a cylinder and covered inside and outside with natural cement mortar. The interior cement mortar core was placed by rolling or revolving the cylinder at a relatively low speed. The exterior mortar was generally applied in the trench by placing a layer in the bottom and shaping it around the pipe by hand.

In Newport, R.I., approximately 15 mi of this pipe, which was installed more than 60 years ago, is still in service. It ranges from 6 to 20 in. in diameter, and operates under normal distribution system pressures. Experience in use of this kind of pipe probably was a factor in the later development of steel cylinder concrete pressure pipe.

Although the types of concrete pressure pipe now manufactured are relatively new, their use has increased rapidly in all parts of the United States. The first reinforced-concrete steel cylinder pressure pipeline was a 36-in. line constructed at Cumberland, Md., in 1919. Prestressed-concrete steel cylinder pipe was first used for water works service in the United States in 1942. Since that time many millions of feet have been manufactured and installed. In the western and southwestern United States, a kind of concrete pressure pipe generally known as "pretensioned concrete cylinder pipe" has been used extensively for a number of years. Another type, which has been used principally for low-pressure lines, is noncylinder concrete pressure pipe which is not prestressed. Within the past 20 years, a prestressed concrete pipe which does not contain a cylinder has been devel-

oped and used principally outside of the United States.

Nonprestressed-Concrete Cylinder Pipe

From 1920 to about 1940 most of the concrete pressure pipe used in the United States by the water supply industry was steel cylinder concrete pipe which was not prestressed. More than 12,000,000 ft of this type has been installed to date. It is manufactured in sizes ranging from 2 ft to more than 12 ft in diameter and for working pressures up to 260 psi.

Modern nonprestressed concrete cylinder pipe consists of a welded steel sheet or steel plate cylinder with steel joint rings welded to its ends; a reinforcing cage or cages of steel rods or bars surrounding the cylinder; a wall of dense concrete covering the steel cylinder inside and out; and a preformed gasket of rubber to provide the joint seal. Prior to about 1935, a preformed lead gasket, calked from the inside, was used instead of a rubber gasket.

The concrete within and outside the cylinder is applied by vertical casting and mechanical vibration. Curing is accomplished by means of water or steam. The pipe is generally made in 12-, 16-, or 20-ft lengths. The circumferential steel of the cage provides 40-80 per cent of the reinforcement, depending on the conditions for which the pipe is designed. Figure 1 shows a longitudinal cross section of steel cylinder concrete pressure pipe which is not prestressed.

Prestressed-Concrete Cylinder Pipe

Prestressed-concrete cylinder pipe was first produced in the United States in 1942. Because of its many

advantages, including a low production cost and excellent performance under various internal pressure and external loading conditions, it has rapidly gained favor in the water industry. Since 1942, 16,000,000 ft of this type of pipe, in sizes ranging from 16 to 120 in. in diameter, has been manufactured in the United States.

There are two general types of prestressed-concrete steel cylinder pipe:

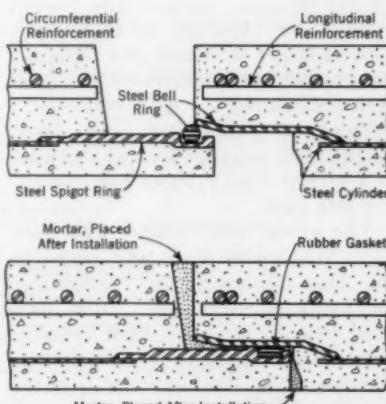


Fig. 1. Cross Section of Nonprestressed-Concrete Cylinder Pipe and Joint

The concrete both within and outside the steel cylinder is applied by vertical casting and vibration. Curing is done by means of water or steam. Mortar is placed after installation.

pipe with a steel cylinder lined with a concrete core and pipe with a steel cylinder embedded in a concrete core. The first, or original, type is furnished in sizes from 16 in. to 48 in. and is designed for pressures up to 250 psi. The embedded-cylinder type, which was developed later, generally ranges in size from 24 in. to 72 in. and is

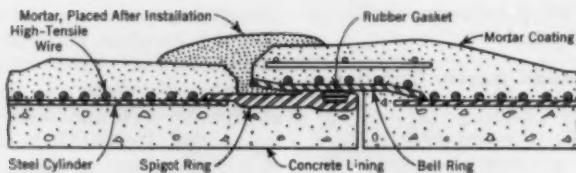


Fig. 2. Lined-Cylinder Prestressed-Concrete Pipe and Joint

The cylinder is lined centrifugally with dense concrete and high-tensile wire is wrapped around the steel cylinder. The wrapped core is then covered with a mortar coating. Joint mortar, of course, is placed after installation.

designed for pressures up to 350 psi. Pipe of larger sizes and pipe designed for greater maximum pressures have been constructed.

Figure 2 shows open and closed longitudinal cross sections of the joint of a typical lined-cylinder prestressed-concrete pipe.

The welded-steel cylinder with joint rings attached is made and tested in the same manner as the cylinder for the nonprestressed pipe. It is then lined centrifugally with dense concrete by rapidly revolving it in a horizontal position. The lined cylinder is cured and then high-tensile wire is wrapped around the core directly on the steel cylinder. The tension of the wire is measured accurately and constantly to

produce a predetermined residual compression in the core. Spacing and size of wire are determined by design requirements. The wrapped core is then covered by a dense premixed mortar coating about $\frac{1}{8}$ in. thick, applied by a mechanical impact method.

A more recent development in prestressed-concrete steel cylinder pipe is the embedded-cylinder type. A longitudinal cross section is shown in Fig. 3. The cylinder and joint rings for embedded-cylinder pipe are constructed in the same manner as for the other types of steel cylinder pipe. The completed cylinder with joint rings is embedded in concrete by vertical casting. After curing, the wire reinforcement is wound, under tension, around

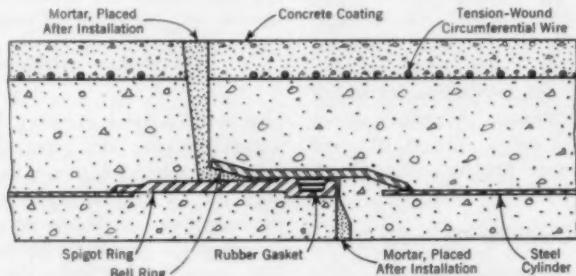


Fig. 3. Embedded-Cylinder Prestressed-Concrete Pipe and Joint

In this type of pipe, the tension-wound wire is wrapped around a concrete core in which the steel cylinder is embedded, rather than around the steel itself.

the outside of the concrete core containing the cylinder, instead of directly on the cylinder. The exterior coating is placed by an impact method of applying premixed concrete or by vertical casting. Embedded-cylinder construction has been found to be superior for large sizes and for pipe designed for comparatively high pressures.

Pretensioned-Concrete Cylinder Pipe

Pretensioned-concrete cylinder pipe is a type manufactured and used for moderate- and high-pressure service in the western and southwestern United States. Figure 4 shows a longitudinal cross section of this type of pipe. The cylinder with joint rings is formed and tested in the same gen-

up to 72 in. in diameter. It is generally made in 32-ft lengths. Used extensively for cross-country transmission mains, it is lighter and less costly than prestressed pipe of the same size and design pressure. Pretensioned-concrete pipe is a semirigid pipe; it deflects slightly from external loads. With the larger sizes, exceptional care must be exercised in providing firm bedding and backfill as these are important factors in keeping the pipe round and within safe limits of deflection.

Noncylinder Nonprestressed-Concrete Pipe

Noncylinder nonprestressed-concrete pipe has been extensively used in the

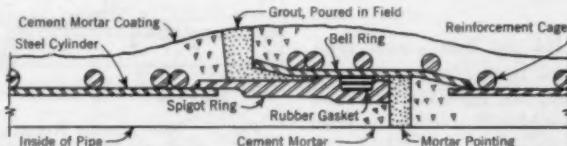


Fig. 4. Pretensioned-Concrete Cylinder Pipe and Joint

Similar to lined-cylinder prestressed-concrete pipe (Fig. 2), this type of pipe is lighter and less costly. It is not as rigid as the former and is used primarily in places where it is not likely to undergo extreme external loads.

eral manner as the cylinder for other types of concrete pressure pipe. The steel used for the cylinder generally is heavier size for size and class for class than that used for other types. The cylinder is lined with cement mortar $\frac{1}{4}$ in. thick. Reinforcing rods are then wound, under measured tension, around the lined cylinder and a $\frac{3}{4}$ -in. mortar coating (measured from the reinforcing rods) is placed by means of pressure equipment.

Pretensioned-concrete cylinder pipe usually is made in sizes ranging from 10 in. to 36 in. in diameter, although some manufacturers furnish it in sizes

water supply industry for low-head transmission lines and similar uses. It usually is not used for internal pressures in excess of about 45 psi. It usually is made with a rubber-and-steel joint, although a similar type of joint, with concrete forming the bell and spigot, is sometimes used. It is made with either one or more reinforcing cages and in sizes ranging from 12 to 144 in. and larger. The concrete is usually placed by vertical or centrifugal casting. Figure 5 shows a longitudinal cross section of this kind of pipe with two reinforcing cages and a rubber-and-steel joint.

Noncylinder Prestressed-Concrete Pipe

In 1937, noncylinder prestressed-concrete pressure pipe was first produced commercially in France. Since that time it has been manufactured and used with varying degrees of success in a number of countries outside of the United States. Only a small number of installations of noncylinder prestressed-concrete pipe have been made in the United States. These include installations made in Chicago in 1941 and in 1943. A number of American manufacturers have, however, spent much time and effort in research toward development of an acceptable noncylinder prestressed pipe that can be manufactured economically.

Pipe Joints

Prior to 1934 the lead gasket type of joint, calked from the inside, was used extensively for concrete pressure pipe. It consisted of a continuous lead gasket calked from the inside between steel bell-and-spigot rings, as shown in Fig. 6.

The rubber-and-steel type of joint shown in Fig. 1-5 has been used almost exclusively since 1934. This joint consists of a flat bell ring and a specially shaped spigot ring with a rectangular groove. A ring rubber gasket of round cross section of proper size is fitted tightly into the groove. When the spigot is fitted into the bell, the gasket is compressed between the steel surfaces of the bell and spigot, providing a watertight seal which remains tight while permitting movement in the joint. The gasket is enclosed on all four sides and is thus protected and held in place. Many tests and years of successful experience have demonstrated the suitability of this joint for concrete pressure pipe.

A number of variations of this type of joint have been developed. A steel sleeve, double rubber gasket joint has been used extensively for low-pressure pipe. Other forms of confined round rubber gasket joints, which do not use steel bell-and-spigot rings, have been developed for use on low-pressure non-cylinder concrete pipe.

Subaqueous Concrete Pipe

Pipe designed for underwater installation is made in the steel cylinder and noncylinder types by most manufac-

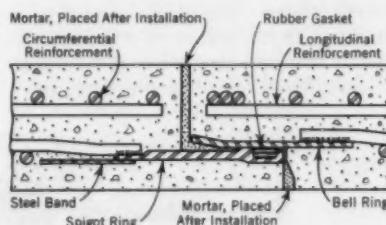


Fig. 5. Noncylinder Nonprestressed-Concrete Pipe and Joint

The pipe shown has two reinforcing cages, although the number may vary with this type of pipe. The joint may also be formed by a concrete bell and spigot, although the use of steel and a rubber gasket is more common.

turers of concrete pressure pipe. Although the joint designs may vary considerably, most subaqueous pipe joints rely upon a confined rubber gasket to provide the watertight seal. The joint may be the conventional steel bell-and-spigot type or some other kind, such as a cast-iron bell-and-spigot joint, an all-concrete joint, or a joint utilizing a glass-reinforced plastic sleeve. If the pipe sections are assembled before laying, two types of joints are sometimes used, one for preassembly and another for underwater connections.

Heavy metal anchor sockets are often attached to the ends of subaqueous pipe at each spring line. Lugs anchored to the sockets receive draw bolts which are used by divers to draw the bell and spigot together and make up the joint. After installation, the bolting, which is only temporary in purpose, should be loosened in order to permit normal settling and joint movement.

Subaqueous pipe can be varied considerably to meet special job requirements. For example, it may be made sufficiently heavy to permit dewatering if so required by the purchaser.

Special Sections and Fittings

Special sections and fittings are made to provide bends, branches, manholes, and connections to other pipe. Long-radius curves are made by slightly opening the joints. Bevel pipes, made by placing the spigot ring at an angle, are used for curves of shorter radius. Fittings for making connections to the concrete pipe are usually built into the pipe when it is made. Equipment and methods also have been developed to permit the installation of service pipe connections and flanged outlets while the pipe is under pressure.

Standards for Concrete Pipe

In April 1943, the Board of Directors of AWWA authorized the preparation of "Tentative Emergency Specifications for Concrete Pressure Pipe." These covered a number of different types in a single document. They served a useful purpose during the war years but are now obsolete.

Since the AWWA Water Works Practice Committee 8320 D—Reinforced Concrete Pipe, was formed in 1946, it has prepared standards for

four types of concrete pressure pipe. These have been revised from time to time to conform to current changes in available materials and improvements in manufacture. Reinforced-concrete pressure pipe of steel cylinder type which is not prestressed is covered by AWWA C300. Both lined-cylinder and embedded-cylinder types of prestressed-concrete steel cylinder pressure pipe are covered by AWWA

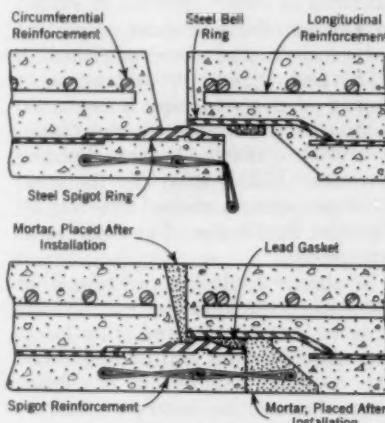


Fig. 6. Lead-and-Steel Concrete Pipe Joint

This type of joint, used extensively prior to 1934, consists of a continuous lead gasket calked from the inside between steel bell-and-spigot rings.

C301. Noncylinder concrete pressure pipe which is not prestressed is covered by AWWA C302 and by ASTM C-361. The use of noncylinder prestressed-concrete pipe in the United States has not yet developed sufficiently to justify the preparation of a standard.

Pretensioned-concrete pressure pipe with steel cylinder is covered by Federal Specification SS-P-381.

Information on Concrete Pipe

Much useful information on design testing, installation, and utilization of concrete pressure pipe has been published in the JOURNAL and other publications during the past few years. In 1950, papers on the design¹ and testing² of prestressed-concrete cylinder pipe were published in the JOURNAL. A summary of results of combined internal and load tests on concrete pipe was published in 1956.³ Results of studies on solution effects of water on cement and concrete pipe were published in 1955⁴ and 1957.⁵ A description of tapping of concrete pipe is contained in an article by Earnhardt and Hasky in 1956.⁶ Water Works Practice Committee 8320D is now in the process of preparing a manual covering all phases of installation of concrete pressure pipe.

In the past, design procedures of various manufacturers have varied because inelastic strains and other losses were accounted for in different ways. The resulting designs did not differ greatly because the factors were based on actual test results. Recently the Specifications and Technical Problems Committee of the American Concrete Pressure Pipe Association has developed a design procedure for prestressed-concrete pipe. A description

of this procedure, which has been adopted by the industry, is given in an article prepared by the chairman of that committee, Robert E. Bald.⁷

It is to be expected that new and improved types of concrete pressure pipe will be developed from time to time, as has been the case during the past few years. This will necessitate revisions in current standards and the preparation of standards for new types of pipe.

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Developments in Plastics and Plastic Pipe

Robert J. Sweitzer

A paper presented on May 19, 1960, at the Annual Conference, Bal Harbour, Fla., by Robert J. Sweitzer, Director of Research, Research Center, Lock Joint Pipe Co., Wharton, N.J.

RESEARCH in plastics is progressing at a rate that causes any article on the subject to become obsolete in a relatively short time. Because of this, and to make the facts presented herein as useful as possible for an appreciable period of time, the foremost producers and research laboratories dealing in plastics were queried to obtain their long-range views on developments in the field.

Definitions

A *plastic* is a material that contains, as an essential ingredient, an organic substance of high molecular weight. It is solid in its finished state but, at some stage in its manufacture or processing into finished articles, can be shaped by flow. A plastic need not be synthetic, although many of the modern important ones are. An example of a nonsynthesized plastic is natural rubber.

A *polymer* (often called a resin) is defined as a compound whose molecules are large multiples of one or more small repeating units characteristically arranged in a chain structure or in a three-dimensional network. It is formed by the process of polymerization of a *monomer*, which is a simple compound that, through a reaction, can be made to form the previously described chainlike structure.

Types of Plastics

Plastics are divided into two general classes: thermoplastics and thermosetting plastics. A thermoplastic is capable of being repeatedly softened by an increase in temperature and subsequently hardened by a decrease in temperature. In other words, it can be formed and reformed repeatedly by application and removal of heat. A thermosetting plastic is one that is capable of being changed into an infusible product when cured by the application of heat or a curing chemical. This means that it can be formed only once.

One of the first commercial plastics was cellulose nitrate, popularly known as celluloid. It was developed by John Wesley Hyatt in the 1860's as an ivory substitute. At about that time, there was a shortage of elephant tusks, used for piano keys, cue balls, and other items. Celluloid is obtained by the partial nitration of cotton linters, a byproduct of the cotton-ginning process. It is classified as a modified natural polymer and a thermoplastic. The development of the product resulted in the formation of a large plastics company,* and celluloid was manufactured by this company until 1948.

* Celluloid Corp., now Celanese Corp. of America, New York, N.Y.

It is a tough, stable material, but it is sensitive to light and highly flammable. The latter property limited the processability and applications of celluloid and eventually led to the development of cellulose acetate in the 1890's.

The second major development in plastics was a phenol formaldehyde, known popularly as bakelite and classified as a thermosetting polymer. It was developed by Leo Baekeland in about 1905. This development gave rise to another large plastics company.* Bakelite is still important, although it is being replaced by newer compounds. Its uses include molded components, among them automotive distributor heads, appliance handles, such laminates as plywood, foundry molds, abrasives, and, in some instances, pipe. The material is hard but brittle, unless reinforced.

First Plastic Pipe

Lucite † and Plexiglas ‡ were among the first materials used in plastic pipe for transportation of food liquids. They are acrylic materials, as clear as glass, weak, brittle, and not highly chemically resistant. Saran § is a vinylidene used for the transportation of corrosive chemicals. It has very good resistance to chemicals, but it is brittle and has inferior aging qualities. Another early pipe material was Haveg,|| classified as a phenolic asbes-

tos. It is used for transporting corrosive chemicals because of its excellent chemical- and heat-resistant qualities, but it is weak, brittle, heavy, and costly. All the early plastic pipe was costly.

Modern Plastic Pipe (Thermoplastics)

In discussions of plastic pipe here, a diameter as large as 12 in. is considered practicable. Commercially important materials used for thermoplastic pipe are: (1) polyethylene, (2) acrylonitrile-butadiene-styrene (ABS), (3) polyvinyl chloride (PVC), and (4) cellulose acetate butyrate (butyrate).

Advantages. Plastic pipe has many advantages. It has good chemical resistance, it is not subject to electrolytic corrosion, and is, normally, affected little by inorganic corrosive materials. Furthermore, it is light in weight, with specific gravities in the range of 0.9-1.4. The specific gravity of iron and steel is 7.8; that of concrete or asbestos-cement, 2.2-2.4.

Plastic pipe has a smooth surface, with a Hazen-Williams coefficient of 150 or more. The pipe maintains this characteristic because it is nonscaling and has a hydrophobic surface. It also acts as a thermal and electrical insulator. In general, plastic pipe is non-contaminating and safe for potable waters and fine chemicals. It is readily handled, formed, machined, and installed.

In the past, the cost of plastic pipe has been too high to permit it to be used widely, but the cost, even of new and better plastics, is steadily decreasing. Some plastics are now competitive in price with carbon steel and are much cheaper than corrosion-resistant alloys. Low installation and mainte-

* Bakelite Co., now Union Carbide Plastics Co., a division of Union Carbide Corp., New York, N.Y.

† Made by E. I. du Pont de Nemours & Co., Wilmington, Del.

‡ A product of Rohm & Haas Co., Philadelphia, Pa.

§ Made by Dow Chemical Co., Midland, Mich.

|| Made by Haveg Industries, Wilmington, Del.

nance costs, as well as the trend to low initial cost, make plastic pipe economically favorable.

Disadvantages. A major disadvantage of plastic pipe is its low mechanical strength. The range of allowable working stresses at room temperatures of the more common thermoplastics is 400–1,800 psi. These values decrease with an increase in temperature. The flexural modulus may be as great as 400,000 psi.

Most plastics are sensitive to temperature and become brittle and difficult to handle at approximately 30°F. They lose a substantial amount of strength at approximately 140°F. The thermal coefficient of expansion is usually rather high, being in the range of $5-15 \times 10^{-5}$ per degree centigrade. Another disadvantage is that, even at low stresses, plastics exhibit undesirable time-dependent properties. Values of long-term rupture stresses are low, and creep values are high. Much has yet to be learned about the long-term—100 years, for example—performance of plastics.

Most plastics are sensitive to such organic solvents as ketones, ethers, and chlorinated hydrocarbons. Most of these solvents will dissolve some of the more commonly used plastics at room temperature, and all of them will cause softening and swelling of the important pipe plastics at room temperature. Also, some plastics are adversely affected by ultraviolet light and weather.

Polyethylene Pipe

Polyethylene pipe is one of the principal kinds of thermoplastic pipe. It comes in three types, each generally defined by its density: Type 1 has a density range of 0.910–0.925 g/cu cm;

Type 2, 0.926–0.940 g/cu cm; and Type 3, 0.941–0.965 g/cu cm. The term density has been used because the three types are known as low-, medium-, and high-density polyethylenes, respectively. The metric density and specific gravity have the same values.

Uses. Polyethylene pipe is used principally for rural and suburban domestic water systems, irrigation, lawn sprinkler piping, mine drainage, and transmission of corrosive liquids.

Advantages. One of the main advantages of polyethylene pipe is its low cost, making it competitive with carbon steel. It is also light in weight, which makes it easy to handle, and comes in long lengths, commercially available in lengths as long as 400 ft, and as long as 2,000 ft on special order. This makes it easy to install and minimizes fittings. The pipe is flexible, thus being able to accommodate moderately abrupt changes of direction in flow without kinking. It remains flexible at subzero temperatures and will not rupture if water freezes in it. The resistance of this plastic to chemicals is excellent. It can be welded to itself with heat, although the welding causes some structural changes in the material. Finally, this pipe is very easy to produce by the extrusion method.

Disadvantages. The mechanical strength and structural rigidity of polyethylene pipe is poor, and it resists heat in a limited range only. Type 1 is softened and Type 3 embrittled by heat at 150°–200°F. The pipe is difficult to join because no satisfactory adhesives or solvents are available. Insert fittings or swaged flanges are generally used.

Polyethylene pipe is sensitive to light and embrittled by ultraviolet ex-

posure, although this is minimized by the addition of carbon black during compounding. It is so flammable that it can be ignited fairly easily with a match. It is somewhat more flammable than soft wood. Although it burns steadily, the flame can be easily extinguished. The material is sensitive to stresses, developing cracks with time at a relatively low stress when it is in contact with certain other materials. Furthermore, the quality of the pipe varies, depending on the producer.

ABS Pipe

Uses. Two types of ABS pipe are available. These are used principally for transmission of chemicals, crude oil, salt water, and natural gas. ABS pipe is also used for irrigation, transmission of potable water and demineralized water, and drainage.

Advantages. The chemical resistance of ABS pipe to nonoxidizing acids, alkalies, and chlorine is very good, and its heat resistance is high. It is also tough and has a high resistance to impact. Its mechanical strength is good for a plastic; tentative allowable working stress at room temperature is 1,800 psi for Type 2 and 1,200 psi for Type 1. The pipe is readily joined because it is capable of being welded by solvents and can be threaded. It is a lightweight material—sp gr 1.1—and is available in both iron pipe and steel water pipe sizes.

Disadvantages. ABS pipe is sensitive to ultraviolet light. Unpigmented ABS exposed to Florida sunlight lost 30 per cent of its impact strength and 70 per cent of its elongation property in 5 months. Its tensile value, however, was not changed. When carbon black is added to ABS, an opaque pipe is produced. But ABS is not recom-

mended for pipe that will be subjected to prolonged exposure to sunlight where flexibility must be retained. ABS is flammable, but its burning rate is slow, similar to that of polyethylene. The organic solvents previously mentioned as affecting plastic pipe will soften and swell ABS pipe.

PVC Pipe

PVC is available in two types: Type 1 is highly resistant to chemicals; Type 2, highly resistant to impact.

Uses. PVC is used for the transmission of chemicals, crude oil, salt water, natural gas, and pickling and photographic solutions. It is also used for irrigation piping, electric cable conduits, potable-water service lines, transmission of foods, drugs, and demineralized water, and is used by the Navy for salt water piping for deck washdowns (principally for washing off radioactivity).

Advantages. PVC is highly resistant to acids, alkalies, and salts in virtually all concentrations. It is also resistant to oxidants, paraffinic solvents, and alcohols. It has good mechanical strength and rigidity, and is virtually unaffected by weather. PVC can be welded to itself by heat and solvents. It threads easily and can be used at temperatures as high as 160°F. It is a self-extinguishing material, available in a complete range of iron pipe sizes, together with valves and fittings.

Disadvantages. PVC is softened by ethers, ketones, and chlorinated hydrocarbons, and is attacked by wet chlorine gas. It is heavy for a plastic (sp gr 1.35-1.40). When it burns, it gives off hydrogen chloride gas. Extrusion of PVC is difficult, but it is now commonly available in good quality.

Butyrate Pipe

Two types of butyrate are available for pipe. Type 1 is transparent; Type 2 is an opaque black.

Uses. Butyrate pipe is principally used for the transmission of salt water, crude oil, and natural gas, and for irrigation.

Advantages. Butyrate resists wax buildup associated with crude-oil transmission, and can be joined easily by a solvent cement.

Disadvantages. The mechanical strength of butyrate is poor, and it is subject to excessive creep. It is sensitive to heat, has relatively poor resistance to chemicals, and is flammable.

Other Thermoplastics

Other thermoplastics are sometimes used for the manufacture of pipe. Fluorocarbons* are highly resistant to chemicals and heat, but they are very costly. Chlorinated polyether† has a performance rating between those of PVC and the fluorocarbons and is similarly priced. Nylon is tough, strong, heat resistant, but not resistant enough to chemicals. It swells to a marked degree on water exposure. Polypropylene is more resistant to heat than is polyethylene. It is less likely to crack, but it lacks flexibility at low temperatures. High-impact styrene has good resistance to low concentrations of chemicals, such as those in sewage. It has fair mechanical properties and is low in cost.

Reinforced Thermosetting Plastics

Thermosetting plastics must be reinforced to be effective for pipe mate-

rial. They are characterized by very great strength and good chemical resistance, but they are very expensive. Although these materials are of only limited interest to the water supply industry, they should be mentioned here.

Glass fiber-reinforced polyester resin has very good initial properties, but it is seriously weakened by water, heat, weather, or erosion. Glass fiber-reinforced epoxy resin is more stable than the polyester. It is very strong and highly resistant to heat, but its applications are limited because it is difficult to join and is expensive. Asbestos-reinforced phenolic resin has very good chemical and heat resistance, but it is heavy, brittle, hard to join, and expensive.

Performance of Plastics

It is important to note the chemical and mechanical behavior of plastics and the different failures of plastic pipe. Some of the terms used to describe these failures are defined and illustrated here.

Chemical behavior. "Solvation" is the phenomenon of absorption of a liquid by a plastic, resulting in softening, swelling, and destruction of many of the properties of the plastic. "Direct attack" is the degradation of the resin molecule—by oxidation or depolymerization, for example—which progresses from the surface through the interior of the resin. This can be brought about by strong acids, alkalies, and ultraviolet radiation. "Environmental stress cracking," the exact process of which is not known, is probably the result of the action of a sensitizing agent on minute surface flaws in a polyaxially stressed polymer. This can be caused by detergents and some other compounds.

* Teflon, for example, made by E. I. du Pont de Nemours & Co., Wilmington, Del.

† Penton, manufactured by Hercules Powder Co., Wilmington, Del.

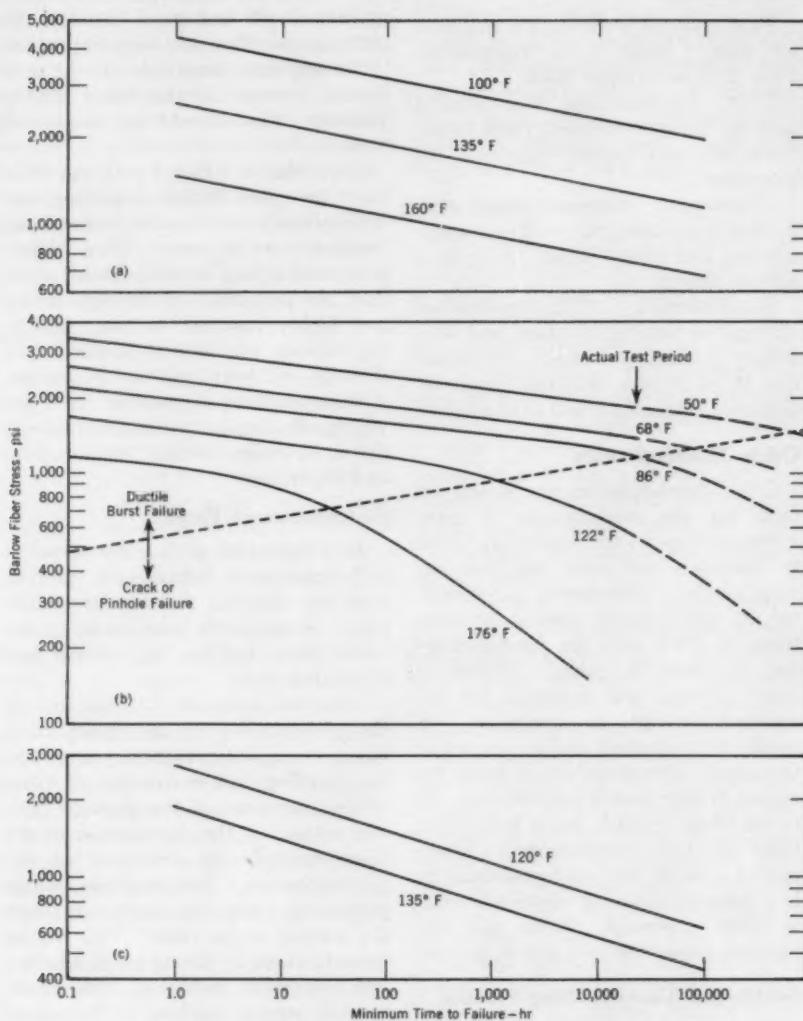


Fig. 1. Relationship of Stress to Failure of Plastic Pipe

Part a refers to Type 2 ABS; Part b, to polyethylene (density, 0.945); and Part c, to Type 2 high-impact PVC (minimum time to failure based on weeping). The fiber stress at failure varied widely with time and temperature in each instance.

Mechanical behavior. The ultimate strength of all plastics is dependent on time. With regard to pipe, two ultimate stresses should be considered: the short-term and long-term burst stresses. Figure 1 shows the log of the stress plotted against the log of the time to failure. It can be seen from Fig. 1a that the fiber stress at rupture varies widely with time and temperature for Type 2 ABS pipe. Figures 1b and 1c show the same property for polyethylene and Type 2 PVC pipe, respectively. The plot of a 1,000-hr-stress life performance allows a reasonable prediction of a 100,000-hr allowable working stress after consideration of experimental scatter. Allowances must also be made for variations in material and manufacture.

All plastics exhibit three types of stress responses. These can be demonstrated by the mechanical model shown in Fig. 2. The first response is like the action of a spring, in which there is an instantaneous elastic movement and recovery. The second is a retarded response, demonstrated by a spring and a dashpot, wherein a mechanism moves slowly from load and recovers equally slowly. The third response, viscous response, is, in effect, a molecular chain slippage. This is represented by the dashpot alone, which responds to long-term load by nonrecoverable deformation.

Figure 3 shows this viscoelastic behavior when a tensile stress is applied to the model. If a weight is hung on an unstressed system, the upper spring immediately stretches, while the two dashpots just start to open. When the load has been applied for some time, the lower spring stretches at a rate controlled by its dashpot, and the lower dashpot is extended. If the

weight is removed, the upper spring snaps back, but the dashpots show no immediate change. With time, the lower spring slowly recovers to its original length. The lower dashpot, however, remains extended after removal of stress. This is a demonstration of the flow or unrecoverable creep component of strain. All three of the responses occur simultaneously, but it

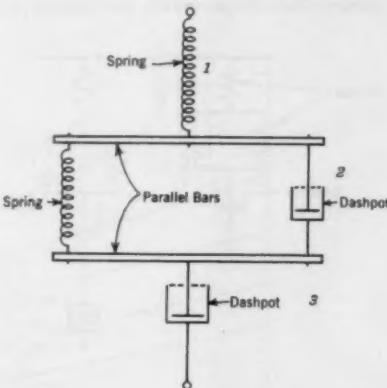


Fig. 2. Apparatus for Demonstration of Stress Responses of Plastics

Numbers refer to stress responses demonstrated by particular parts of the mechanical model: at 1, instantaneous elastic response (chain stretching and recovery); at 2, retarded elastic response (chain uncurling and recurling); and at 3, viscous response (chain slippage).

is the third type of response, viscous response, that keeps the safe working stress of most plastics at a low value.

Figure 4 shows the creep of Type 1 PVC at two temperatures and at several stresses. After the initial movement, the increase in percentage of creep can be represented by a nearly straight line of gradual slope. Poly-

ethylene exhibits the same type of creep curve as PVC (Fig. 5), except that the stress and temperature levels are much lower. Also, the less dense of the two polyethylenes shows the greater creep under the same test conditions. The most desirable plastic would be one that exhibited an almost flat curve past the 100,000-hr point at a practical stress loading.

Theoretically, the plotting of creep values should permit a prediction of

of misapplications, faulty installations, or irresponsible production techniques. In some foreign countries, principally in Germany and Holland, PVC pipe has been continuously used to convey water and acid materials for 25 years or more.

Orientation

The mechanical properties of nearly all plastics can be improved by a process called orientation. This is some-

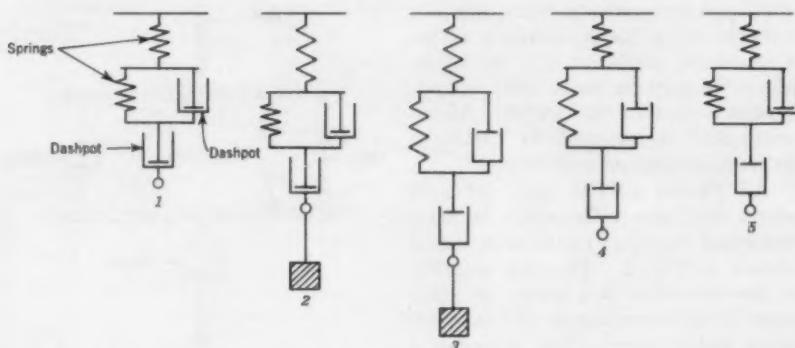


Fig. 3. Interpretation of Stress Responses of Plastics With Time

Number 1 is the unstressed system. At 2, a weight is added, and the upper spring immediately stretches, while the two dashpots start to open. At 3, the weight has been applied for some time, allowing the lower spring to stretch at a rate controlled by its dashpot and allowing the lower dashpot to extend. At 4, when the weight is removed, the upper spring snaps back; the two dashpots show no change. With time, the lower spring recovers slowly, but the lower dashpot remains extended, as shown at 5.

service life, depending on temperature, pressure, and time. But because time cannot be varied or compressed, precise values are unavailable and can be taken only from extrapolated data.

In spite of difficult evaluation techniques and the complicated chemical and mechanical behavior of plastic materials, the service record of some plastic pipe has been found to be good. Nearly all failures have been the result

what analogous to improving the tensile properties of steel by "cold working." When plastics are oriented by the application of stress, their random molecular configurations become partially aligned in the direction of the tension. This increases the strength of amorphous plastics. Some crystallization occurs, and the crystallites tend to arrange themselves parallel to the direction of stress. Crystalline poly-

mers are those that contain crystalline regions as shown in Fig. 6. The crystalline structure is represented in the figure by parallel lines, and the amorphous material by irregular lines between the crystalline portions. The parallel-lined portions are known as crystallites.

Some recent experiments demonstrated that one plastic subjected to relatively little stress for a long period of time actually doubled its short-term

Irradiation

Some plastics may be strengthened by irradiation, but this is relatively costly and is not being used widely. Irradiation causes some cross linking of the polymer chains, thus increasing the strength of the plastic.

Suitability of Plastic Pipe

A few years ago, the plastic pipe industry found that certain unscrupulous suppliers were using scrap and

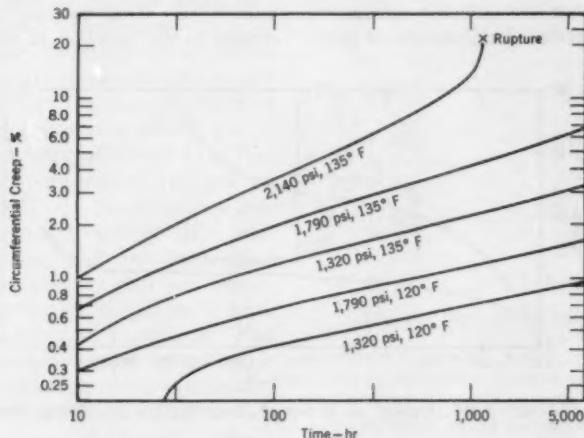


Fig. 4. Creep of Type 1 PVC Pipe at Different Stresses and Temperatures

After the initial pipe movement, the increase in percentage of creep can be represented by a nearly straight line of gradual slope.

rupture stress. Perhaps an explanation of this phenomenon, although a less scientific one than given before, is that when certain plastics are subjected to slowly applied loads, orientation of the polymer causes an increase in strength at a greater rate than the application of the load causes a diminution of the cross section. This can be demonstrated mechanically by orienting small pieces of plastic. Some ductility is sacrificed by orientation.

reclaimed material for the production of pipe, which subsequently was used for potable-water service. Some unfortunate experiences occurred. In order to protect itself, the industry retained the services of the National Sanitation Foundation (NSF), Ann Arbor, Mich. This organization is a certifying agency that, among other activities, tests and approves the product of certain suppliers of plastic pipe. Studies were made of:

1. Extraction of plastic by aggressive waters
2. Impartion by plastic of taste, odor, and color to water
3. Performance of plastic pipe after exposure to weather, soil, and water
4. Effect on plastic of chlorine-bearing fluids
5. Susceptibility of plastic to rodent attack.

Some other minor tests were performed. After exhaustive studies, NSF determined that all basic types of thermoplastics are safe for fabrication into pipe for the transmission of pota-

Association, American Petroleum Institute, American Society for Testing Materials, American Standards Association, Bureau of Reclamation, Federal Housing Administration, International Standards Organization, Society of the Plastics Industry, and AWWA.

Among the large potential users of plastic pipe, an increased interest in the material is being shown by several industries: the chemical, natural gas, petroleum, sewerage, and water supply industries. This interest is demonstrated by the increase in sales volume

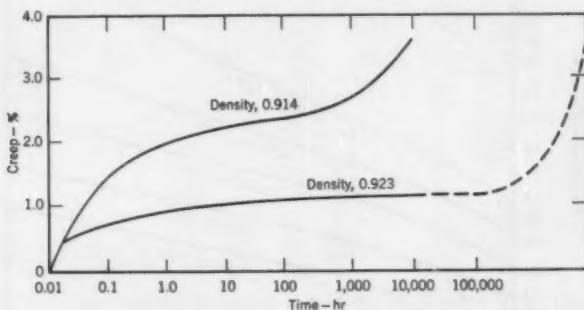


Fig. 5. Effect of Density on Creep of Polyethylene at 200-psi Stress

The creep curve of polyethylene is similar to that for PVC.

ble water. Several states now include plastic pipe in their sanitary codes under stipulated conditions. These states are: Arkansas, California, Illinois, Maine, and Wisconsin.

Standards

A number of commercial and organizational standards on plastic pipe and fittings have been prepared. Several government agencies, industrial consumers, and others have developed procurement specifications. The organizations actively studying and developing standards are: American Gas

over the past few years. The amounts given in Table 1 are for all plastic pipe; sales values are on the consumer level. The 1959 sales of plastic pipe are shown in Table 2.

Future Prospects

The pace of all types of research is accelerating. In the field of plastics, this acceleration is greater than in most other fields of research. Many of the resins now available or being developed by research scientists will be of use for water pipe. Some of the requirements for continued progress in

TABLE 1
*Value of Plastic Pipe Sold**

Year	Sales Value \$
1948	500,000
1958	50,000,000
1959	60,000,000
1960	70,000,000†
1961	80,000,000†

* Values are on the consumer level.

† Estimated value.

the development of plastics are increased working stress levels, easier joining, and less temperature sensitivity.

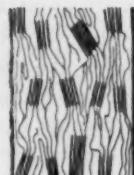
For domestic water piping—that is, pipe used for plumbing—it would be desirable to have a material that would be cheaper than copper and have a rated working pressure of 150 psi at 200°F. The material should have rigidity at this temperature and not be brittle at 40°F. It should have a low thermal expansion within this temperature range, and its installation should be as easy as that for copper tubing. Service life should be at least 50 years under these conditions. For water transmission and distribution, pipe size becomes an important factor. Sizes of 4, 6, 8, 10, and 12 in. cannot be obtained economically until working stresses are improved. Rigidity with an economical wall thickness must be attained. The pipe must be reliable, easily joined, easily tapped,

and resistant to all hazards common to the water supply industry. For sewage pipe, requirements are essentially the same as those for water pipe, except that the working stress can be lower, and the cost must be lower.

The plastics industry today has available better materials that, as yet, cannot be fabricated into pipe. Some resins, known by such names as polyamides, polyacetals, and polyolefins, can be produced and upgraded to molecular weights in the range of 200,000–2,000,000. These resins can withstand stresses over a long period of time.



Unoriented



Oriented

Fig. 6. Crystalline Polymer

As stress is applied, the crystallites tend to orient themselves parallel to the direction of stress, resulting in a substantial increase in tensile strength.

They have working stresses in the range of 3,000–8,000 psi. Although the resins are now available, there is no equipment that can make them into pipe, because of their high viscosity when melted.

Other new materials show a great deal of promise, among them a thermosetting hydrocarbon,* carbonates,† and chlorinated polyethers. Most of

* Buton, manufactured by Enjay Co., Elizabeth, N.J.

† Lexan and Merlon, manufactured by General Electric Co., New York, N.Y., and Mobay Chemical Co., Pittsburgh, Pa., respectively.

TABLE 2
Sales of Plastic Pipe, 1959

Plastic	Amount Sold 1,000,000 lb	Percentage of Total Sales
Polyethylene	45	72.0
ABS	9	14.4
PVC	7	11.2
Butyrate	1.5	2.4
<i>Total</i>	62.5	100.0

these materials are potentially very cheap, but some of the more promising ones are costly now because of low volume production. When demand increases and methods of polymerization are improved, costs will decrease. For example, not too long ago, PVC pipe compound cost about 50 cents a pound. Now it is available in large lots at about 40 cents a pound. The prices of other resins have also decreased.

Future developments in fabrication include methods for postextrusion cross linking or orientation, cellular (foamed) construction, and reinforced construction. There is no question that research will provide plastics and methods of processing them which will enable the water supply industry to use better pipe. Better materials for water pipe have been found; now they must be made economical.

Acknowledgments

The author thanks H. F. Mark, director of the Polymer Research Insti-

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Loss in Pipeline Carrying Capacity Due to Corrosion and Tuberculation

Thurston E. Larson

A paper presented on May 17, 1960, at the Annual Conference, Bal Harbour, Fla., by Thurston E. Larson, Head, Chemistry Sec., State Water Survey Div., Urbana, Ill. The study was supported in part by Research Grant 4007 from the National Institutes of Health, USPHS.

AN analysis of factors that result in a loss in pipeline carrying capacity must take into account: (1) the nature of the problem; (2) the fact that there is no cure-all or magic formula to remedy the problem, because the qualities of waters, like distribution systems, and even portions of systems, differ; (3) that corrective measures will increase the cost and effort of operations; (4) that conditions of use affect the corrosive and inhibitive properties of water—that is, a water may have both corrosive and inhibitive properties at the same time, but its behavior will depend on how it is used; and (5) that considerable research is needed on the mechanics and chemistry of corrosion, as well as on associated tuberculation and its prevention.

For purposes of review, it should be pointed out that the carrying capacity of any pipeline or transmission line may be reduced in several ways, aside from blockage by silt and debris or from structural failure. Soft slime deposits may cling to pipe walls and develop wavy or ridged roughness. Such roughness often results in a much greater loss of capacity than is apparent from the thickness of the deposits. The deposits may consist of:

1. Bacterial growths, with or without iron and manganese
2. Soft deposits of aluminum hydroxide, resulting from improper filtration or from after-precipitation when coagulation is not effective
3. Soft deposits of magnesium hydroxide, resulting from ineffective coagulation or improper filtration.

Scale deposition may consist largely of excessive calcium carbonate or magnesium hydroxide at heating temperatures, or of iron oxide as a loose or uniform deposition of corrosion product, or the deposits may come from natural iron in the water. With waters containing dissolved oxygen, tuberculation in the form of nodules or spicules may occur at intermittent locations on the pipe wall. Because tar-coated pipe is used extensively, it seems to be subject to difficulty more frequently than other materials; but with unstable waters, nodules and corrosion or dissolution can also develop on materials that are not ferrous. These latter types of resistance to flow of water and the effect of low velocities in dead-end areas merit discussion. It also seems pertinent to note that measures for the prevention of tuberculation involve measures for the prevention of corrosion.

Although these measures may prevent the occurrence of red water, tuberculation may still occur if the problem is not adequately dealt with.

Corrosion Inhibitors

Studies with aerated waters, made by the Chemistry Section of the State Water Survey Division at Urbana, Ill., have shown, without doubt, that each of three factors serves to inhibit corrosion rates.¹ These are calcium, alkalinity, and pH, usually in increasing concentrations. When their proportions are such that a condition of sufficient supersaturation exists with respect to calcium carbonate solubility, the tendency toward corrosion and tuberculation can be made essentially nonexistent. Tuberculation results when corrosion is almost, but not completely, prevented by this treatment. Further, when this proportion is such that the pH of saturation is low—that is, with more calcium and higher alkalinity—the saturation index necessary for protection approaches zero. But as the calcium and alkalinity concentrations decrease, it becomes increasingly difficult to overcome the tendency toward corrosion and tuberculation. Where such treatment is not applied to very soft waters, tuberculation results because of partial protection by the reaction of oxygen with the corrosion products.

Studies²⁻⁴ have also shown that alkalinity (greater than 100 ppm), in the absence of, or with very low concentrations of, calcium, serves as a weak inhibitor of corrosion, in contrast to the effect of chloride and sulfate ions. Inhibition is least strong at approximately pH 8.0-8.5, because, as indicated by Stumm,⁵ the buffer capacity of the carbonate-bicarbonate equi-

librium is decreased at the phenolphthalein endpoint by a factor of 10, relative to the buffer capacity at pH 7.0 and at approximately pH 9.5. With strongly buffered waters, as influenced by the alkalinity concentration and by pH, the ability of corrosion products—that is, OH⁻ at the cathode and H⁺ at the anode—to self-accelerate corrosion is less than with weakly buffered waters.

Calcium Carbonate Stability

It has also been demonstrated that the velocity of water flow influences the effectiveness of calcium carbonate stabilization and determines whether a stabilized water can cause tuberculation or a relatively protective action. These laboratory studies have been concerned with flat specimens of bare cast iron, exposed at room temperature to constant water velocities of 0.1-2.0 fps. The results, therefore, are indicative of, but only indirectly associated with, experience in the field. At each existing distribution system, however, the established principles concerning stability must be considered in relation to the prevailing environmental conditions.

It is time that the demonstrated principles of calcium carbonate stability and velocity be given a more complete evaluation, not only in relation to tuberculation and corrosion as they exist but also to corrective measures and to new installations or changes in water sources and quality. The principle of calcium carbonate stability is the one most widely applied and found to be most widely effective in treatment for the protection of distribution systems, although there are many notable exceptions to this principle.

Saturation Index

The equation for the saturation index was explained by Langelier⁶:

$$I = \text{pH} - \text{pH}_s = \text{pH} - K + \log \text{Ca} + \log \text{Alk}$$

in which I is the saturation index; pH , the actual pH ; and pH_s , the pH at saturation. K is $\log \frac{K_s}{K_z}$ (K_s and K_z are

thermodynamic constants, corrected for ionic strength and temperature).

The equation may also be expressed as:

$$\text{antilog } I = \frac{(\text{Ca})(\text{Alk})}{K'(\text{H}^+)} = \frac{\text{H}_s^+}{\text{H}^+}$$

in which K' is the antilog of K . These relationships exist:

$$\text{If: } I = 0; \text{ antilog } I = 1.0$$

$$I = +0.4; \text{ antilog } I = 2.5$$

$$I = +1.0; \text{ antilog } I = 10.0.$$

Another way of using this index is to relate the actual pH to the imaginary calcium and alkalinity concentrations that would exist if the actual concentrations were decreased by equal amounts until equilibrium existed with the actual pH . Then:

$$\begin{aligned} I &= \text{pH} - \text{pH}_s \\ &= K - \log \text{Ca}_s - \log \text{Alk}_s - K + \log \text{Ca} \\ &\quad + \log \text{Alk} \end{aligned}$$

or

$$\text{antilog } I = \frac{\text{H}_s^+}{\text{H}^+} = \frac{K'(\text{Ca})(\text{Alk})}{K'(\text{Ca}_s)(\text{Alk}_s)}$$

If x is the excess of calcium and alkalinity, then:

$$\frac{\text{H}_s^+}{\text{H}^+} = \frac{(\text{Ca})(\text{Alk})}{(\text{Ca} - x)(\text{Alk} - x)}$$

and x , the initial excess, can be calculated. This method of calculation indicates a temporary excess but not the ultimate or equilibrium excess, which is always smaller.

Ryznar⁷ emphasized the importance of the concentrations of calcium and alkalinity to scale-forming properties:

Ryznar index

$$= 2\text{pH}_s - \text{pH}$$

$$= 2K + 2(\log \text{Ca}) + 2(\log \text{Alk}) - \text{pH}$$

or

$$\frac{\text{H}^+}{(\text{H}_s^+)^2} = \frac{(\text{Ca})^2(\text{Alk})^2}{(K')^2 \text{H}^+}$$

Ryznar stated that the scale-forming tendency increased as the ratio of $\frac{\text{H}^+}{(\text{H}_s^+)^2}$ decreased from 10^6 (Ryznar index less than 6).

McCauley⁸ recently proposed a driving force index (DFI):

$$DFI = \frac{(\text{Ca}^{++})(\text{CO}_3^{--})}{K_s \times 10^{10}}$$

with which he precalculates the carbonate ion concentration from the alkalinity, pH and K_s .

All of these approaches recognize a weakness in the saturation index as a direct criterion of the magnitude of excess calcium carbonate. Incidentally, Langelier never intended it to be such a criterion, other than as a relative indicator that was subject to interpretation. Langelier emphasized that the index "is an indication of directional tendency and of driving force, but it is in no way a measure of capacity."⁹

Caldwell and Lawrence⁹ established curves from which the equilibrium excess calcium carbonate could be determined for water at temperatures of 25°C and 100°C. These curves are not entirely adequate for waters at lower temperatures, but they are helpful because interpretations for other temperatures can be derived.

The relative excesses of calcium carbonate at 25°C (77°F) are shown in

Fig. 1. This is perhaps the best numerical indicator of the available calcium carbonate that may be expected from supersaturated water and is similar to the momentary index reported by Dye.¹⁰ The reaction rates, however, are still dependent on: (1) tem-

protective concentration after the deposition of a unit of calcium carbonate. These data on excess calcium carbonate may be made more useful by the inclusion of a measure of the buffering capacity related to the concentrations of calcium and alkalinity.

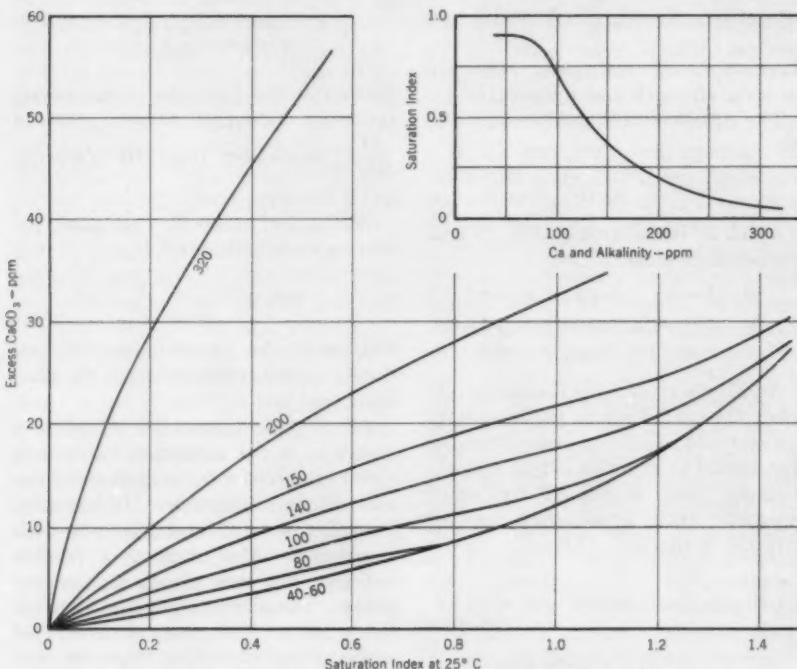


Fig. 1. Excess Calcium Carbonate From Supersaturated Water

The values on the curves represent equal calcium and alkalinity (as CaCO_3) concentrations in parts per million. The inset shows the curve for 10 ppm excess calcium carbonate.

perature, (2) the influence of OH^- and H^+ developed at cathodic and anodic areas of the corroding surface, and (3) the buffering effect of greater concentrations of both calcium and alkalinity in the water. This buffering effect might be considered as the ability to maintain a potential or latent

Velocity of Flow

Inevitably the distribution rate of protective components going to metal surfaces must be considered. Because metals react with water, the composition of the water—that is, H^+ and OH^- produced by corrosion reaction and side reactions—at the metal surface is

not the same as in the body of the water. The consistent failure to recognize this fact is perhaps the greatest source of misinterpretation of field experience. In corrosion experience, it is well known that, to protect metals under conditions brought about by stagnant water, highly excessive inhibitor concentrations must be used. Such conditions often dictate the use of cathodic protection for corrosion prevention.

It has always been an accepted fact that, where flow rates are low, dead

to the reaction products of corrosion was suggested by the author at the AWWA Indiana Section meeting in 1959. At the 1959 AWWA Annual Conference at San Francisco, it was shown that velocity (rate of flow) affects tuberculation (Fig. 2). Baylis,¹¹ in 1953, also showed the effect of velocity. McCauley⁸ gives strong weight to this factor. Eliassen and others,¹² in 1956, related corrosion rate to velocity for a water with a negative saturation index. They indicated that the increasing velocity decreased the path

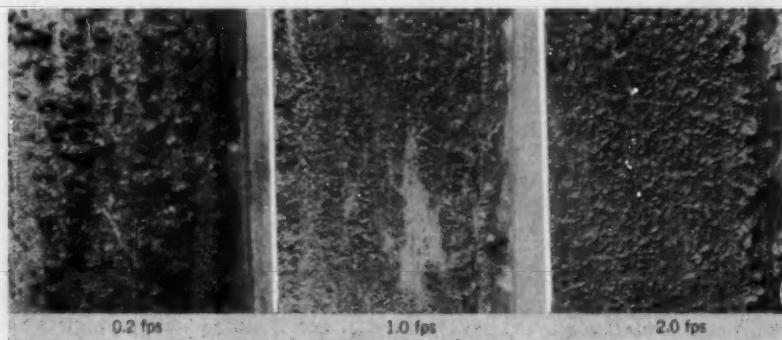


Fig. 2. Effect of Velocity on Tuberculation

The test was made with the use of Champaign-Urbana tap water at the velocities shown beneath each photograph. The corrosion rate after 120 days was 1 mg/sq dm/day.

ends are often the most troublesome areas in distribution systems, with regard to tuberculation, red water, and, often, tastes and odors. The reasons for the difficulty are the long time of contact that causes the accumulation of iron resulting from corrosion and the fact that the protective ingredients in the water are not made to act at the point of corrosion and on the surface of the metal.

The concept of employing mechanical means to bring the protective ingredients to the pipe surface and thus

of diffusion of oxygen through the laminar flow layer adjacent to the pipe wall. The oxygen in this non-protective water thereby accelerated corrosion.

The thickness of the laminar layer also limits the rate of diffusion of ions to the pipe surface. For a water with sufficient protective characteristics, the effect of oxygen can be nullified, or even be made to contribute to the protective action, when the thickness of the laminar layer is reduced. This thickness (δ) is related to velocity

(V) ¹³ and arbitrarily to the friction factor (f) by:

$$\frac{V\delta}{\nu} = \frac{32.8}{\sqrt{f}}$$

and therefore, in turn, related to the Reynolds number, $\frac{VD}{\nu}$ (Fig. 3). D is the diameter; ν , the viscosity. Be-

turbulent pipe flows is usually considered to be between the limits for perfectly smooth pipe and limiting velocities beyond which there is complete turbulence—that is, no change in friction factor. The Hazen-Williams C has been plotted in Fig. 3 for a velocity of 4 fpm, but there is very little difference in the position of the curves at other velocities.¹⁴

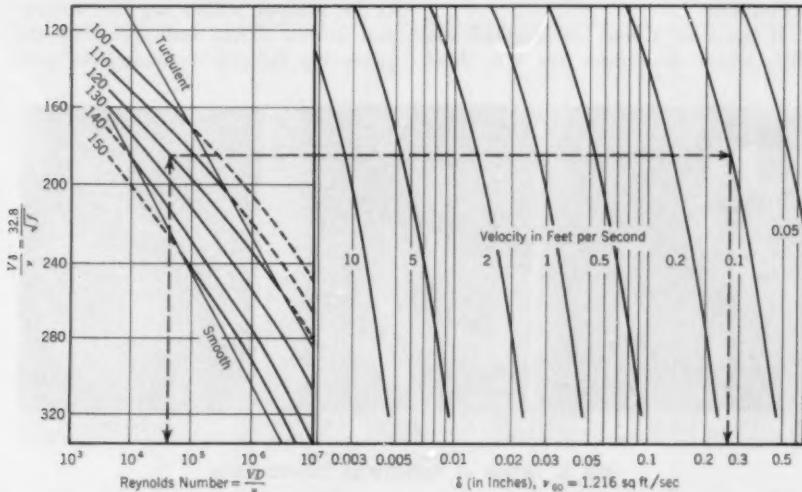


Fig. 3. Relationship of Laminar Flow Layer Thickness, Friction, and Reynolds Number

The values on the curves in the left portion of the figure represent the Hazen-Williams coefficient. The thickness of the laminar flow layer is greater for smooth pipe than for rough pipe. This diffusion is decreased by approximately half as the velocity is doubled.

cause the Hazen-Williams coefficient, C , is normally used by water utility investigators to establish roughness of pipe and is determined from the same measurements of velocity and head loss, the relationship between the Reynolds number and the Hazen-Williams coefficient is introduced to indicate the laminar thickness at various velocities. In water supply practice, the range of

It will be noted that the velocity of flow plays an important role with regard to the thickness of the laminar flow layer, which is decreased by approximately half as the velocity is doubled. It will also be noted that this thickness is greater for smooth pipe than for rough pipe. For instance, with a C coefficient of 145 for the example indicated in Fig. 3, the thickness would

be approximately 0.32 in., which indicates the greater need for higher velocities at new installations. This, in part, may explain discrepancies in observed tuberculation at various locations in the same community.

Figure 3 does not show the effect of temperature. Temperature affects the viscosity (ν), which, in turn, may increase the thickness of the laminar layer by approximately 30 per cent as the temperature decreases to 35°F.

A recent JOURNAL article¹⁶ gives an example of corrosion inhibition by the combined application of calcium carbonate stability and velocity. In the instance described, a community had suffered from red-water problems for nearly 25 years. The system was designed for fire flows greater than 500 gpm, but the demand was approximately 500 gpd. The *maximum* demand velocity in the residential area was about 0.04 fps in 6-in. pipe, which is a flow rate in the laminar range of the Reynolds number. Induced circulation at 60 gpm helped alleviate the distribution system problem, but data showed that corrosion continued until pH adjustment to a +0.3 saturation index eliminated the problem. When the induced velocity was reduced to 30 gpm (0.4-0.9 fps), a saturation index of approximately +0.6 was necessary to avoid corrosion by this water, which was softened by ion exchange and had a 90-ppm hardness.

Other Variables

It was mentioned earlier that much remains to be learned about the chemistry and mechanics for the prevention of corrosion. At the present time, essentially nothing is known about the effect of silicates, polyphosphates, or

aluminates. Studies should also be made on the effects of detergents, tannins, and organic color as influenced by specific qualities of water and flow characteristics. Until the effects of these factors are known, further advances in corrosion prevention will be limited.

Conclusions

It should be recognized that calcium carbonate stability must be classified as an adjunct to natural or artificial protective coatings on metals. This is true because the quantity of available protective ingredient is limited for any water and may not be sufficient to neutralize or react with the quantity of products resulting from corrosion—that is, the rate of reaction of inhibiting agents may not equal or exceed the rate of production of corrosion products from an unprotected metal. It is also clear that higher velocities of flow, even if induced by the aid of applied energy, improve the efficiency of calcium carbonate stability by bringing the protective ingredients more rapidly and in greater volume (or mass) to the point of corrosion reaction.

The saturation index can indicate the quantity of available supersaturation of calcium carbonate. But there is also a need for a numerical parameter that can indicate, more effectively than the saturation index, the latent buffer capacity of water to yield more available calcium carbonate by reaction with the OH^- corrosion product. Other aids or inhibitors may also be beneficial under certain conditions. These aids should be studied and reported *only* for specific test conditions or applications.

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Estimating Human Radiation Exposure on the Animas River

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John D. Jones, and Don A. Clark**

A paper presented on May 19, 1960, at the Annual Conference, Bal Harbour, Fla., by Ernest C. Tsivoglou, San. Engr. Director; S. David Shearer Jr., Sr. Asst. San. Engr.; John D. Jones, Asst. Sanitarian; and Don A. Clark, Chemist, all of Radiological Pollution Activities, Div. of Water Supply & Pollution Control, Field Operations Sec., Robert A. Taft San. Eng. Center, Cincinnati, Ohio.

THE USPHS has recently completed comprehensive studies of radioactive pollution of the Animas River, an interstate stream, under responsibilities provided in the Federal Water Pollution Control Act. The studies were conducted as a result of the interstate pollution abatement enforcement action instituted by USPHS at the request of New Mexico. They illustrate several of the basic principles that are important to the rational, successful control of radioactive water pollutants and provide a practical case study that may be useful as a guide for solving future problems of radioactive liquid waste control.

The Animas receives wastes from a uranium ore refinery in Durango, Colo., and flows south into New Mexico. It is the main source of water for the area and is used for domestic water supply, irrigation of croplands, recreation, and waste disposal. Figure 1 shows the pertinent area and the location of communities and river sampling stations.

The communities of Aztec and Farmington in New Mexico, with populations of approximately 6,000 and 22,000, respectively, obtain their water

supplies from the Animas and treat them in conventional, complete treatment plants. In addition, an estimated 2,000 ranchers and farmers along the river use Animas water in its raw state for domestic purposes. The river is also used to irrigate approximately 26,000 acres, primarily in the New Mexico reaches.

Radioactive Wastes

The uranium mill at Durango processes approximately 500 tons/day of uranium-bearing ore from nearby mines. It performs the initial extraction of uranium from the raw ore. The resulting uranium concentrate is shipped to other establishments for further processing and the eventual manufacture of reactor fuel elements and weapons.

Natural uranium is the initial member of a long chain of radioactive elements including isotopes of thorium, polonium, bismuth, radium, lead, and others. All of these radioactive materials are found naturally with the uranium. Only the uranium is desired, and all the other radioactive materials constitute process wastes. These wastes occur as both liquid and solid

materials. From the 500 tons/day of raw ore received at the mill, approximately 3,200 lb/day of uranium concentrate are obtained. Essentially, then, 99.7 per cent of the raw ore solids appear at the end of the process as wastes, called "tailings." These

of the main survey of the Animas River, in the summer of 1958, essentially all the liquid wastes were discharged directly into the river. The wastes carried with them approximately 15 tons per day of spent ore solids.

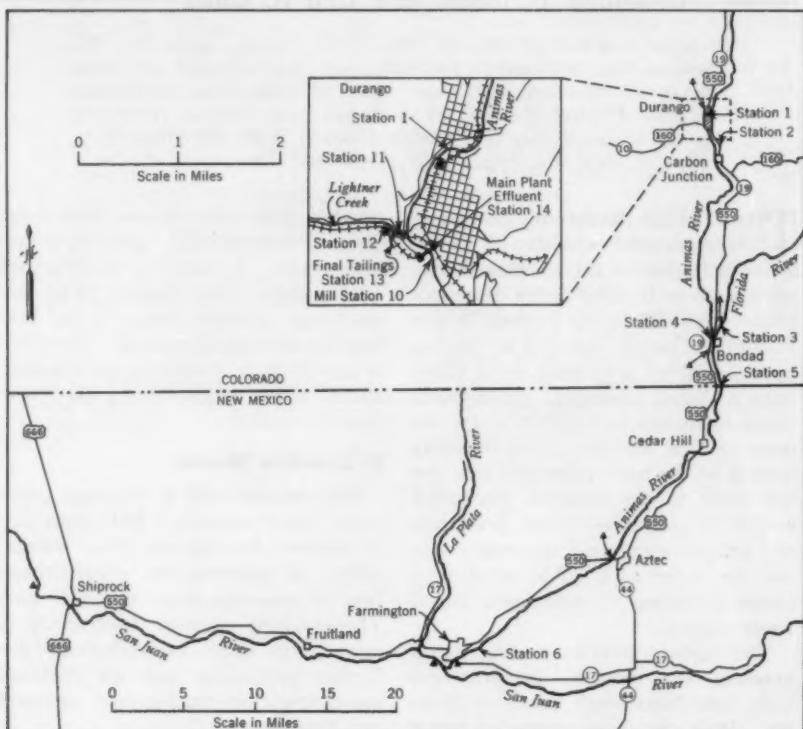


Fig. 1. Animas River and Vicinity

Representative samples of river water, muds, and biota were collected at several stations along the 60 mi of Animas River. Black triangles represent gaging stations.

solids accumulate in a tailings pond, or lagoon, and are pumped to that location as a slurry. Liquid wastes include several of the mill process streams, as well as overflow of the excess liquids from the tailings pond. At the time

The most hazardous radioactive material involved in wastes from the uranium ore-refining process is Ra^{226} . As will be discussed later, the allowable concentration of radium in a domestic water supply is exceedingly

small when compared to the allowable amounts of more usual contaminants, and the ingestion of excessive quantities of radium from water or any other medium must be prevented. The presence of other radioactive materials further complicates the problem. A brief discussion of the general principles of radiation protection is pertinent before the details of the Animas River study are examined.

Total Internal Radiation Exposure

The world environment presently contains small amounts of a large variety of radioactive materials. Uranium, thorium, and all of their daughter products are present in small concentrations everywhere and create a natural background radioactivity that has always existed. In addition, fallout from past nuclear weapons tests has distributed such fission products as radiostrontium and radiocesium to some degree throughout the world environment. For practical purposes—the detection of pollution, for example—these fission products now constitute a portion of the background radioactivity. Background radioactivity, then, is made up of a natural and a manmade component.

As a result of the total environmental radioactivity that presently exists, water, milk, and foods in general all normally contain some amount of radioactivity. Radioactive materials, such as radium and radiostrontium, may therefore be ingested in a number of ways, of which the drinking of water constitutes only one. The chemical and metabolic characteristics of these radioactive materials resemble those of calcium. On ingestion, these materials find their way to the human skeleton. While in the bones, they undergo radioactive decay, and the alpha, beta,

and gamma radiations that are emitted bombard the surrounding tissue. It is these radiations that must be minimized.

In this regard, the radium or radiostrontium may be ingested by way of water, milk, or food. In estimating the radiation dose, it is important to learn how much may be ingested from each of these; the total amount of radioactive material ingested will be the sum of those portions ingested by each route. It is the total quantity ingested daily that is of importance, rather than the concentration in water or, for that matter, in milk or any particular food.

The fundamental approach in radiation protection is to minimize the radiation dose to any particular body organ, such as the skeleton or the thyroid gland. The method is to minimize the total intake of all radioactive materials that would find their way to that organ. For example, the total intake of all bone-seeking radioactive materials is minimized in order to limit the radiation dose received by the skeleton. Certain radioisotopes are considered more hazardous than others because of such factors as the sensitivity of the body organ involved, the residence time in this organ, and the nature and energy of the radioactive emissions. Based on such criteria, the bone-seekers, Ra^{226} and Sr^{90} , are classed as relatively hazardous materials in terms of the concentrations that may occur in water.¹⁻⁴ In the Animas River studies, although other bone-seekers (thorium, for example) may also have been present, the data indicated that their relative concentrations were slight. The problem, for practical purposes, concerned Ra^{226} and Sr^{90} . The latter was an uncontrollable, general environmental contaminant, present as a result of fallout from past

nuclear weapons tests. Hence, the minimization of radiation exposure involved essentially the reduction of Ra²²⁶ released from the uranium mill.

It also follows from the foregoing that if part of the radiation dose to the bones comes from Sr⁹⁰, then the amount of radium intake should be reduced accordingly. In the Animas studies, the Sr⁹⁰ concentration in water was shown to be relatively low, but a significant amount was contained in local crops. The natural background Ra²²⁶ concentration in water was also low, but some occurred in local crops. The actual radium concentration in downstream water supplies was significantly high because of pollution. The reason for this is of great interest and illuminates the question of the fate of radioactive materials in streams.

The Animas River studies constituted a first attempt to estimate the total internal radiation exposure of a local population group on the basis of environmental sampling. In order to make such estimates, with separate evaluation of the effects of fallout and industrial pollution, collection and analysis of a wide variety of samples over a relatively long period were required. Details of sample collection and analysis are contained in earlier reports.^{5, 6}

Standards of Protection

Basic standards for the protection of workers against excessive exposure to individual radioisotopes were recommended in 1953 by the National Committee on Radiation Protection and published by the National Bureau of Standards.¹ The standard values were later reduced by a factor of 10 for the protection of the general public.² Maximum permissible concentra-

tions (MPC's) for the individual radioisotopes were derived; these referred to the amount of radioisotopes that could be ingested, by way of a domestic water supply, continuously during a lifetime without producing readily detectable biologic damage.³ A recently published handbook⁸ revises the MPC's for the exposure of radiation workers, but does not provide figures for the protection of the general public, except by reference to the recommendations of the International Commission on Radiological Protection.⁴ The latter recommendations, together with recent statements of the Federal Radiation Council,^{7, 8} provide the presently accepted basis for control of radioactive wastes.*

In the light of the most recent references, the presently accepted limits for the protection of general population groups are, on the average, 3.3 μmc per liter or kilogram of total dietary intake for Ra²²⁶ and 33 μmc per liter or kilogram for Sr⁹⁰. These figures are based on the estimated average daily adult intake of 2.2 liters or kilograms of water or food. As a result, the recommended limits are 7.3 and 73 $\mu\text{mc}/\text{day}$ of Ra²²⁶ and Sr⁹⁰, respectively. It is these quantity figures that are of most use in estimating human radiation exposure.

The above limits are intended to apply as *average* intakes on an annual basis, rather than as maximum intakes.

* Since the preparation of this article, the Federal Radiation Council has adopted the use of the terms "radiation protection guide" and "radioactivity concentration guide," rather than "maximum permissible concentration." The numerical guides, however, are not yet available. Hence, the recommended numerical limits, as used in this article, must still be referred to as maximum permissible concentrations.

It is recognized that local variations in concentration of the radioisotopes, as well as variations in the dietary habits of individuals, will bring about deviations from the recommended average exposure limits. As a result, the recommendations⁴ allow for individual departures as large as three times the average figures. Thus, it has been estimated that if a population group ingests, on the average, 7.3 $\mu\text{c}/\text{day}$ of Ra²²⁶, a few individuals within the group may ingest as much as 7.3×3 or 21.9 $\mu\text{c}/\text{day}$.

An example of the application of the above figures may be of help. Should studies disclose that, as a result of nuclear weapons testing, the total average daily intake of Sr⁹⁰ by all paths is 20 μc , or approximately 30 per cent of the allowable average amount, it would be advisable to hold the total daily intake of Ra²²⁶ to no more than approximately 5.0 μc , or 70 per cent of its allowable amount. In this way, the total radiation dose that might be delivered to the bones should be held to no more than the recommended limits.

Regardless of the exact numerical recommended limits, however, it is generally agreed that all human radiation exposure should be held to a minimum. An *ad hoc* committee of the National Committee on Radiation Protection has made a statement in this regard:

Finally, the committee wishes to emphasize that under one of the primary assumptions made in this report (non-threshold linear dose response), the biological effect does not suddenly change from harmless to harmful if any permissible dose is exceeded. Any permissible level which may be chosen is essentially arbitrary, and every effort should be

made to keep the radiation dosage as far below the permissible level as feasible. On the assumption noted above, any radiation dose should be thought of as being tolerated only to obtain compensatory benefits.⁹

The Animas River situation was approached with this philosophy in mind.

Survey Methods

Because the concern here is with standards that refer to chronic lifetime exposure to low concentrations of materials, it is not feasible to estimate human radiation exposure over too brief a survey period. Accordingly, the Animas River studies lasted a full year, so that seasonal and annual exposures could be evaluated. An intensive survey period of 2 months was followed by a less intensive sampling period of an additional 10 months, in order that annual exposure might be estimated.

Representative samples of river water, river muds, and river biota were collected at several locations (Fig. 1) along the 60 mi of the Animas River south of Durango. In addition, representative samples of crops grown locally by the use of Animas River irrigation water were obtained, as were local milk samples. Precipitation samples were collected routinely during the intensive 2-month survey period at both Durango, Colo., and Farmington, N.M. During this same period, samples of the effluents from the uranium mill were collected and composited for analysis.

All samples were analyzed for gross alpha and beta radioactivities, as well as for Ra²²⁶. Selected samples were analyzed for uranium and for Sr⁹⁰, Sr⁸⁹, and certain other fission products

that might be present. Samples of raw water and treated water from the plants at Aztec and Farmington, N.M., were composited on a weekly basis during the 2-month survey period and on a monthly basis during the following 10 months. These samples were also analyzed for Ra²²⁶ as well as for gross radioactivity. Filter sand samples from the two treatment plants were also collected occasionally for these analyses. Details of the sample collection and compositing procedures, as well as of the analytic methods, are presented elsewhere.⁵

The gross alpha and beta analyses proved most useful in delineating and limiting the scope of the problem. For example, they showed conclusively that bone-seekers other than radium and strontium were not present in significant concentrations, and thus showed that there was no need for analysis of samples for thorium and other specific radioisotopes.

Total Radiation Exposure

Estimates of the total average internal radiation exposure of humans to Ra²²⁶ and Sr⁹⁰ were made from the survey data (Table 1). In brief, the amount of Ra²²⁶ and of Sr⁹⁰ ingested as a result of water consumption has been estimated on the basis of the generally used intake of 2.2 liters per day per person and on the observed concentrations in the water supplies. For example, the average Ra²²⁶ intake from water by people at Aztec was estimated to be 7.9 $\mu\mu\text{c}/\text{day}$, or 109 per cent of the recommended limit of 7.3 $\mu\mu\text{c}/\text{day}$. A large variety of vegetable and crop samples was analyzed for Ra²²⁶ and Sr⁹⁰. The figures for the daily intake of these isotopes from food and milk were derived on the basis of the observed concentrations

and the makeup of a standard diet (a moderate-cost diet for physically active men).¹⁰ In each instance, the daily intake in micromicrocuries of Ra²²⁶ and Sr⁹⁰ was estimated on the basis of the observed sampling and then expressed as a decimal percentage of the recommended limits (7.3 $\mu\mu\text{c}/\text{day}$ for

TABLE 1
Estimated Average Exposure to Ra²²⁶ and Sr⁹⁰:
Water Year, 1957-58*

Radioactive Material	Population Groups			
	Durango, Colo.	Consumers of Untreated River Water	Aztec, N.M.	Farmington, N.M.
Percentage of Recommended Limit				
Ra ²²⁶ in water	10	230	109	79
Sr ⁹⁰ in water	3	3	3	3
Ra ²²⁶ in food & milk	43	61	61	61
Sr ⁹⁰ in food & milk	53	53	53	53
<i>Totals</i>	100	347	226	196

* At the time of preparation of the Animas River report,⁵ the generally accepted MPC's of Ra²²⁶ and Sr⁹⁰ in water were 4 and 80 $\mu\mu\text{c}/\text{day}$, respectively.^{1,2} On the basis of the intake of 2.2 liters per person per day, the allowable daily intakes were 8.8 and 176 $\mu\mu\text{c}$, respectively, and average human exposure estimates were based on these figures.^{5,11} The more recent recommended limits used⁴ are lower. Hence, the figures in the table are somewhat higher, especially for Sr⁹⁰, than the comparable figures in the Animas River report. Specifically, for Ra²²⁶, the figures in the table are higher by the factor $\frac{4.0}{3.3}$; and for Sr⁹⁰, by the factor $\frac{80}{33}$. These changes have resulted because of the changing recommended limits. Thus, for instance, an average daily intake of 50 $\mu\mu\text{c}$ of Sr⁹⁰ would represent 69 per cent of the most recent recommended limit (7.3 $\mu\mu\text{c}/\text{day}$),⁴ but only 28 per cent of the older limit (176 $\mu\mu\text{c}/\text{day}$).^{1,2}

Ra²²⁶ and 73 $\mu\mu\text{c}/\text{day}$ for Sr⁹⁰). In this way, it was possible to arrive at an estimate of the total human internal radiation exposure by summing up the derived fractions. Details of these computations are given in a recent report.⁵

It was estimated that approximately 109 per cent of the suggested allowable amount of Ra^{226} was ingested, on the average, from the domestic water supply at Aztec. Only approximately 3 per cent of the allowable amount of Sr^{90} was ingested from this source. Approximately 61 per cent of the allowable daily Ra^{226} intake and approximately 53 per cent of the allowable Sr^{90} intake were ingested from food and milk, on the basis of an analysis of locally produced samples. The sum of these figures showed that average members of this population group ingested approximately 226 per cent of the combined allowable amounts of Ra^{226} and Sr^{90} . In other words, the Aztec group, on the average, ingested approximately 125 per cent more of these radioisotopes than the limit recommended for general population exposure. It must be recalled in this regard, however, that the recommended limits for ingestion are based on the concept of lifetime exposure. Hence, the ingestion of somewhat more than these amounts over a relatively short period of time is not regarded as an immediate hazard but rather as a long-term hazard that can still be brought under control in time to prevent harm to the population group.

It should also be noted that some members of such a population group may actually ingest less, and others more, of the radioisotopes in question because of individual dietary, economic, and other deviations from the assumed norm. The figures may therefore be either higher or lower in individual cases. As has been noted, the recommended limits for average exposure of general population groups incorporate some allowance for such individual variations.

As may be seen from Table 1, the group having the highest exposure, as well as could be estimated, was the approximately 2,000 individuals who consumed Animas River water in the raw state. This is not meant to imply that water treatment effected any removal of radium from the water consumed by other groups, but that the radium concentrations in the river water at the point of use were higher than the radium concentrations in the raw water supplies at Aztec and Farmington. Some reduction in these radium concentrations occurred between this point of use and Aztec as a result of the withdrawal of irrigation water and the dilution of the river water downstream with return irrigation flows. Further reduction may have occurred as a result of the uptake of radium by the aquatic biota. This population group, as a result, ingested on the average approximately 350 per cent of the combined recommended limits of Ra^{226} and Sr^{90} . The Farmington population ingested about twice as much Ra^{226} and Sr^{90} as the suggested limits allow.

In contrast, the Durango population group, where the radioactive wastes originate, ingested about 100 per cent of the total allowable combined amounts of Ra^{226} and Sr^{90} . The difference between this group and downstream populations is clear from the data. Durango's water supply was from a different stream, uncontaminated by uranium mill wastes, and contained, as a result, only the natural background concentrations of Ra^{226} , or approximately 10 per cent of the recommended limit. The quantities of radium ingested with food and milk were smaller than those ingested in the New Mexico reaches, because of the use of uncontaminated river water

for irrigation of farms near Durango. More than half the exposure of this group was the result of Sr⁹⁰ in food and milk.

It must be emphasized that such estimates of human radiation exposure still leave certain questions unanswered. One of the most important of these questions concerns the lack of exact knowledge about the metabo-

the area being considered the exact quantities of various types of water and food consumed daily by local populations. For instance, the New Mexico reaches of the Animas River are a relatively arid area, which might well raise the average quantity of water consumed daily. No investigation of this factor was possible at the time of the studies. It was necessary instead

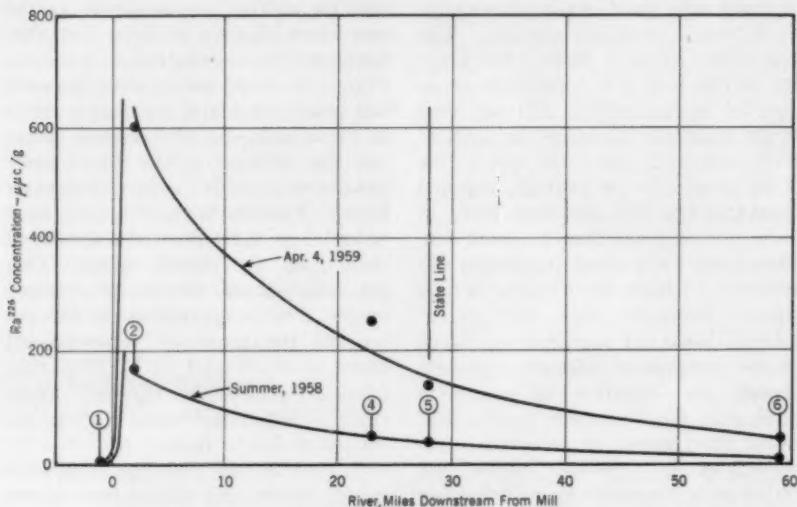


Fig. 2. Radium Concentration in Animas River Muds, 1958-59

Although the contamination of river sediments diminished as one proceeded downstream, it did not, throughout the entire 60 mi of river, diminish to natural background concentrations. Solid circles designate sampling stations.

lism of these radioisotopes once they are taken into the human body. In other words, there is still the question of how much Ra²²⁶ and Sr⁹⁰ is retained in the body and gets into the bones once ingested. This depends on many physiologic and local factors, the investigation of which was beyond the scope of these studies. Nor was it possible to determine specifically for

to adopt standard and generally accepted estimates of average daily intake of water and food.

These questions serve only to indicate the extent of research and investigation that is necessary in order to estimate precisely the human radiation exposure in a particular area and under particular circumstances. It is believed, nevertheless, that the studies

reported here provide a rational and reasonably adequate approach to the problem of control.

In interpreting the results of such environmental surveys, one must also be able to extrapolate to conditions at other times. For example, in the study involving the Animas River, the water year 1957-58 was a relatively wet year, in which there was relatively large dilution available in the receiving stream. The survey data, therefore, were also projected to the water year 1955-56, which was a drier year, with somewhat lower flows in the Animas River. Less dilution was available during 1955, with resulting higher concentrations of radium in the receiving stream and higher levels of human radiation exposure. These figures were given in a previous report.⁵

Another factor that had to be considered was the question of possible expansion of milling capacity in the near future at the uranium ore refinery. Specifically, it was anticipated that the refinery would soon increase its capacity to 700 tons/day of ore, as compared to the 500 tons/day being processed during the field survey. It was therefore necessary to be able to extrapolate survey figures on a rational basis in order to make estimates of the resulting increase in downstream radium concentrations and population exposures. These figures were also reported before.⁵

Radioisotopes in a Water Environment

In general, the recommended limits for human radiation exposure are based on estimates of what will happen to specific radioisotopes once they are ingested by humans. In other words, these figures are thought to represent

safe concentrations of radioisotopes at the point of use. There has been some tendency to use such figures as effluent standards¹²—that is, as allowable concentrations in effluents before dilution in a receiving stream—and to assume, therefore, that downstream water supplies will be automatically protected. This assumption is not always true, because the behavior of radioisotopes in a water environment is, at times, unpredictable. The Animas River study illustrates such an instance. It indicates clearly that before effluent standards are fixed, the fate of radioactive materials in the water environment must be ascertained. Furthermore, one must be especially cautious about adopting as effluent standards figures that were developed on the basis of the behavior of radioisotopes in the human body.

The situation on the Animas River, regarding waste discharges of Ra²²⁶ in the dissolved and undissolved state by the uranium mill, illustrates the importance of the foregoing considerations. Effluent sampling showed that the effluents from the uranium mill contained, on the average, approximately 0.5 mc/day of Ra²²⁶ dissolved in the liquid portion of the effluent. In addition, the undissolved solids in these effluents carried an estimated 30 mc/day of Ra²²⁶ to the Animas River. These solids settled out in the river and formed a reservoir of undissolved radium in the river muds and sediments. Figure 2 shows the extent of radium contamination of the river muds downstream from the uranium ore refinery. During the summer of 1958, the radium content of river muds increased from a natural background concentration of approximately 1 $\mu\text{mc/g}$ at Station 1 upstream from the

uranium mill to approximately 200 $\mu\text{c/g}$ at the next station downstream, approximately 2 mi from the uranium mill. This contamination of the river sediments was at a maximum immediately downstream from the uranium mill and diminished as one proceeded

Animas River, with little runoff due to precipitation and minimum flows during the entire 6 months (Fig. 3). These flows were conducive to sedimentation. Figure 2 shows the Ra^{226} concentration of river mud samples collected early in April 1959. As

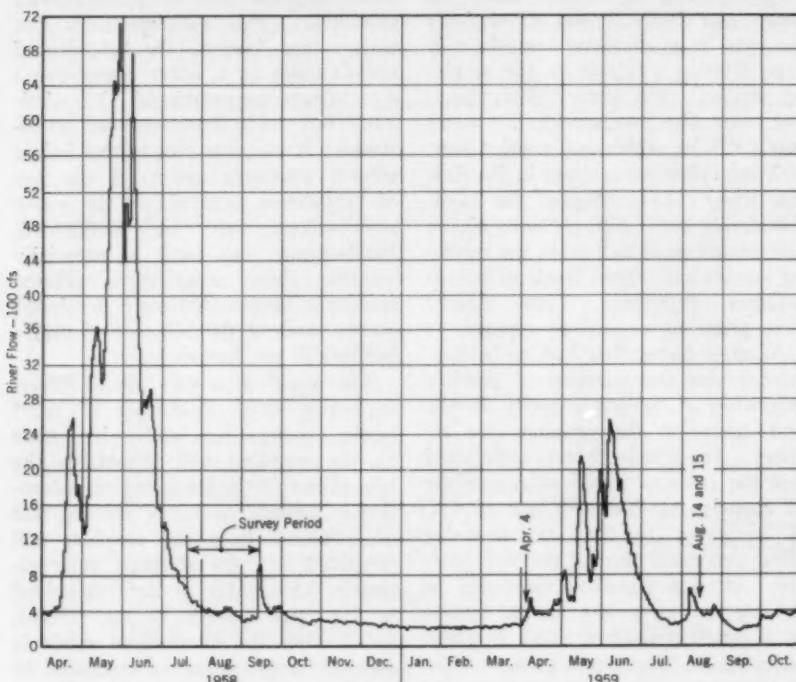


Fig. 3. Animas River Flow at Durango

The low-flow period, September 1958–March 1959, was conducive to sedimentation. The flood flows during the late spring and early summer of each year scour the river bed and cleanse it of prior accumulations of radium.

farther downstream. But the contamination did not again, throughout the entire 60 mi of river, diminish to natural background concentrations of Ra^{226} .

The period September 1958–March 1959 was a low-flow period on the

shown in the figure, this extended period of undisturbed accumulation of spent ore solids from the uranium mill resulted in considerably higher radium concentrations in the river sediments. The concentrations at Station 2, just downstream from the uranium mill,

had increased to 600 $\mu\text{rc}/\text{g}$. Then the concentrations diminished, proceeding downstream, in the same orderly fashion as was observed in 1958.

Samples of river water from the same river sampling stations provide direct evidence regarding the effects of these river sediment accumulations of radium. Table 2 shows the dissolved-Ra²²⁶ concentration of river waters for the summer of 1958 and for the samples taken on Apr. 4, 1959. The results for the summer of 1958 are averages for 2 months of continuous sampling, whereas the results for Apr. 4, 1959, represent instantaneous or grab samples taken just before the onset of the spring floods.

Table 2 shows that during the summer of 1958, the increase of dissolved radium in the river water between Stations 1 and 2, immediately upstream and downstream from the uranium mill, was 11.0 mc/day. The effluents from the uranium mill contained only 0.5 mc/day of Ra²²⁶ in the dissolved state. It is clear that approximately 90 per cent of the dissolved Ra²²⁶ in the river water downstream from the mill must have resulted from the mill discharges of *undissolved* radium. The relatively large reservoir of Ra²²⁶ in the river sediments was steadily leached by the flowing water in such a way that a substantial portion of this initially undissolved Ra²²⁶ dissolved into the river water and appeared downstream as dissolved Ra²²⁶.

This conclusion is further demonstrated by a comparison of the dissolved-radium concentrations in river water during the summer of 1958 with those in April 1959. Figure 2 shows that the undissolved-radium reservoir in the river sediments was approximately three times higher in April 1959 than in the summer of 1958. The

data in Table 2 show that, at all sampling stations, this increased radium content of the river muds was directly reflected by a proportionate increase in the dissolved-radium content of the river waters. These results describe the short-term fate of initially undissolved Ra²²⁶ in the Animas River environment. It follows that radioactive materials that are discharged into rivers in the undissolved state may be leached, more or less, by the flowing water and may appear later as dissolved radioactivity.

The ultimate fate in the water environment of these radium accumula-

TABLE 2
*Dissolved-Ra²²⁶ Concentration
in Animas River*

Station	Distance Down- stream From Uranium Mill mi	Summer 1958		Apr. 4, 1959	
		Concentration			
		$\mu\text{rc}/\text{l}$	mc/day	$\mu\text{rc}/\text{l}$	mc/day
1	-1.0	0.4	0.54	0.1	0.08
2	2.0	12.6	11.5	24	18.8
4	23	7.2	7.2	19	14.9
5	28	7.6	8.0	16	12.5
6	59	2.9	1.6	6.7	4.0

tions is also clear from the data. In Fig. 3, sharp increases in flood flows may be noted during the late spring and early summer of each year. These floods scour the river bed thoroughly and cleanse it, insofar as prior accumulations of Ra²²⁶ are concerned. This is why the radium accumulations in river muds during the late summer of 1958 were considerably less than those observed during early April 1959. The data for the summer of 1958 represent only approximately 6-8 weeks of undisturbed sedimentation and accumulation of spent ore solids

on the river bed, whereas the data of Apr. 4, 1959, reflect an extended period of 8 months of undisturbed sedimentation and accumulation. The floods of May and June 1959 then flushed these radium accumulations out of the Animas River Basin and into the San Juan River. Also, during the early summer of 1959, waste treatment measures instituted at the uranium mill succeeded in retaining a much larger portion of the spent ore solids and in preventing their discharge to the river. Only very small quantities of ore solids reached the river after July 1959. As a result, river mud samples taken during the late summer of 1959 contained only a small fraction (approximately 10 per cent) of the radium concentrations observed during the summer of 1958, 1 year earlier.

The dissolved-radium content of the river water at Station 2 and at subsequent stations downstream from the uranium mill reflected this cleansing of the river bed. The average dissolved-radium concentration at Station 2, immediately downstream from the mill, was reduced to only 4 $\mu\text{mc}/\text{l}$ during September and October 1959. This represents approximately a 70 per cent reduction in the dissolved-radium concentration of river water as measured against the concentration in the same period in 1958. Similar reductions were observed at all downstream locations.

The spring floods that cleanse the Animas River annually of its radium accumulations lift these sediments and transport them in the flowing water. The bulk of them are carried by the Animas into the San Juan River downstream from Farmington, and similar floods on the San Juan carry them further into the main Colorado River

system. Eventually, they find their way into the sediments of the great reservoirs of this river. For practical purposes, this is their ultimate resting place.

One other aspect of the fate of this initially undissolved radium is worthy of consideration. The radium-bearing sediments and undissolved solids transported by the river water at any time of the year find their way into the rapid sand filter beds at downstream water plants. As will be shown, the small amount of undissolved radium-bearing solids that found its way into the sand filters at the water treatment plants had a discernible effect on the dissolved-radium content of the water supplies.

It is clear, then, as regards the Animas River situation, that by far the most important waste disposal and pollution problem arose because of the discharge of initially undissolved spent ore solids, and not because of discharges of dissolved Ra^{226} . And yet, until June 1959, with the publication of the National Bureau of Standards' Handbook 69,⁸ no suggested standard was available regarding the discharge of undissolved radium in the environment (the MPC's of Handbook 52¹ refer to dissolved radioactive materials).

Handbook 69 included, for the first time, suggested limits for undissolved (or "insoluble") radioactive materials. The handbook indicates that the recommended limit for undissolved Ra^{226} for ingestion by "persons in the neighborhood of controlled areas" is $3 \times 10^{-5} \mu\text{c}/\text{cc}$, or $3 \times 10^4 \mu\text{mc}/\text{l}$. This is a somewhat higher concentration of undissolved Ra^{226} than was actually found in the mill effluents during the 1958 survey and, had this figure been used as an effluent standard or as an

allowable concentration in the stream environment, the dissolved-radium concentrations in the Animas River would have been higher than those observed during the 1958 survey. Specifically, with the mill effluent flows as measured during the 1958 survey and a concentration in the effluent of $3 \times 10^4 \mu\text{c/l}$ of undissolved radium, a discharge of 65 mc/day of undissolved radium into the Animas River would have resulted. This is just twice as much undissolved radium as was actually discharged during 1958. Had this recommended limit been the actual concentration in the mill effluents, the radiation exposure of downstream populations would have been nearly double that observed. Thus, it is clear that "point of use" standards are not always acceptable as effluent standards, insofar as radioactive materials are concerned.

One further facet of the fate of Ra²²⁶ in the water environment is illustrated by the Animas River data. As has been noted, a rather large variety of crop samples from irrigated farms in the Animas River Valley was collected and analyzed for Ra²²⁶. Samples were collected from three farms that used unpolluted Animas River water for irrigation purposes. Samples were also collected from six farms in the downstream reaches of the river which utilized the polluted Animas River water for irrigation. Comparison of the analytic results indicated that, on the average, crops raised on farms that used polluted Animas water contained twice as much Ra²²⁶ than did similar crops that were grown on the upstream farms that used unpolluted water. As most of the dissolved radium in the river water was traceable to effluent discharges of undissolved

radium-bearing ore solids, it must be concluded that the contamination of locally raised crops resulted largely from the discharge of undissolved ore solids. Samples of the aquatic biota (algae, insects, and fish) also indicated some uptake and concentration of Ra²²⁶. The concentration factors in fish were not high enough to be considered significant in terms of human exposure, although they were of interest as a means of further examining the fate of Ra²²⁶ in the water environment.

These studies of the pollution of the Animas River by refinery wastes from uranium ore demonstrate clearly the importance of having factual information regarding the fate of radioactive materials in water before a decision is made on an acceptable effluent or stream standard. In view of the general lack of knowledge on this subject, because the Animas River represents only an isolated case, one can only conclude with the National Committee on Radiation Protection that discharges of radioactive materials into streams should be restricted to the minimum that is practicably attainable.

Treatment Plant Samples

As previously mentioned, sampling and analysis of the raw and treated supplies at Aztec and Farmington were carried on as a part of the general Animas River studies. The resulting data will be discussed at length. It is pertinent here, however, to emphasize that one is dealing with exceedingly small concentrations of radium. The recommended limit of dissolved Ra²²⁶ in a domestic water supply is $3.3 \mu\text{c/l}$. In this particular instance, a curie is the same as a gram; hence the limit is $3.3 \mu\text{g/l}$. This

amount of material may be compared, for example, to allowable amounts of such common poisons as arsenic or lead in drinking water. The allowable concentration for arsenic in the USPHS Drinking Water Standards¹³ is 0.05 mg/l. On conversion, this amounts to 50,000,000 $\mu\text{g/l}$, or 12,500,000 times the allowable Ra^{226} content. An attempt is being made to control the radium content of a domestic water supply to a very high degree, a degree entirely new to the water supply field.

ters at each water plant, taken immediately before and after backwash, were also analyzed for Ra^{226} .

Figure 4 shows the dissolved- Ra^{226} concentrations in raw and treated Aztec water for all samples. These data may be compared to the usual natural background concentration for dissolved radium in the Animas River of 0.1–0.3 $\mu\text{c/l}$. It is evident from the data for late August and September 1958 that the treated water contained slightly more Ra^{226} than did the raw water supply at Aztec. For the

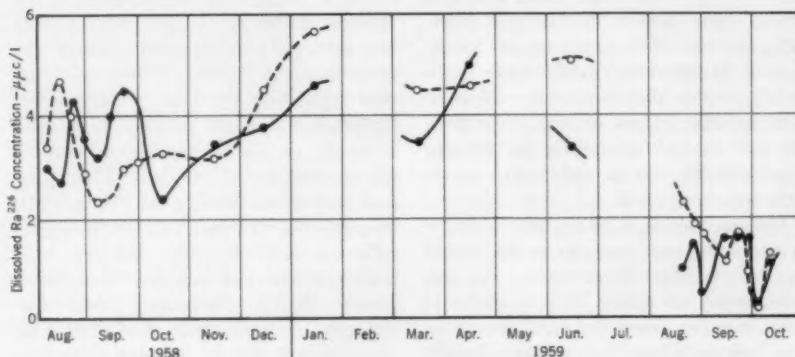


Fig. 4. DISSOLVED-RADIUM CONCENTRATIONS IN AZTEC WATER

Solid curves represent treated water; dashed curves, raw water. The data indicate that the treatment plant itself cannot be depended on to remove substantial quantities of radium by conventional treatment.

During the 2-month survey in the late summer of 1958, samples of raw and treated waters at both Aztec and Farmington were collected four times daily and composited into weekly samples for analysis. After that period, and until June 1959, water samples were collected once daily and composited into monthly samples. These samples were analyzed for dissolved Ra^{226} . In a few instances, the filtered solids were also analyzed for Ra^{226} . Occasional samples from the sand fil-

8 weeks of survey, the average figure was 3.4 $\mu\text{c/l}$ of dissolved radium in the raw water as compared to 3.6 $\mu\text{c/l}$ in the treated water. As will be seen, this difference is explained on the basis of the radium content of filter sands. The data also indicate that the water plant itself cannot be depended on to remove substantial quantities of radium by conventional treatment. Had water softening been practiced at these communities, different results might have been achieved.

The rise in dissolved radium concentrations during the winter of 1958-59 is also clear from the figure and is directly traceable to the steady accumulation of radium-bearing ore solids on the river bed during the low-flow winter months.

Remedial measures to abate pollution were instituted at the uranium ore refinery during the summer of 1959. These will be discussed later. Data in Fig. 4 on the raw and treated concentrations of dissolved radium during the period late August-mid-October 1959 should be noted: the dissolved-radium concentrations in both raw and treated waters had been markedly reduced by the upstream remedial measures, and averaged, in early October, approximately $1.0 \mu\text{c/l}$. It should also be noted that during this sampling period in late 1959, the dissolved-radium content of the raw water was generally the same or higher than the dissolved-radium content of the tap water. This will also be explained later in terms of the radium content of the filter sands at that time.

Figure 5 shows comparable data for the Farmington water supply. During the period August-September 1958, the raw water generally contained a little more dissolved Ra^{226} than did the treated water. This was the reverse of the situation at Aztec at that time. The average figures for this period were $2.8 \mu\text{c/l}$ of dissolved Ra^{226} in the raw water as compared to $2.6 \mu\text{c/l}$ in the treated water. This relationship, whereby the raw water contained somewhat more radium than the treated water, continued at Farmington to the end of June 1959—that is, to the end of the spring flood period—and the usual increase of dissolved radium concentrations is also apparent for the winter months. Dur-

ing the period August-October 1959, however, the situation reversed. At Farmington, the treated water, on the average, contained slightly more dissolved Ra^{226} than did the raw water. It should also be noted that the dissolved-radium concentrations in both the raw and treated waters were sharply reduced during late 1959 because of the remedial measures put in effect at the uranium mill. It is also evident that conventional treatment at Farmington, without water softening, did not dependably remove Ra^{226} from the water supply.

The suspended-solids fractions of raw and treated water supplies at Aztec and Farmington during October-December 1958 were also assayed for Ra^{226} concentrations. The average Ra^{226} concentrations of suspended solids in the raw water supplies were 3.3 and $3.2 \mu\text{c/l}$, respectively. At Aztec, at that time, a small amount ($0.13 \mu\text{c/l}$) of suspended Ra^{226} persisted in the treated water, while at Farmington all three monthly composite samples of treated water contained $0.0 \mu\text{c/l}$ of suspended Ra^{226} .

Table 3 shows the results of radium analysis of filter sand samples. During the summer of 1958, the filter sands at Aztec contained an average of approximately $27 \mu\text{c}$ of Ra^{226} per gram of dry filter sand. At Farmington, the figure was only $4.7 \mu\text{c/g}$. These figures may be compared with a natural background Ra^{226} concentration of approximately $1.0-2.0 \mu\text{c/g}$. The figures are consistent with the differences noted in the dissolved- Ra^{226} concentrations at the water plants. Those data showed that the treated water at Aztec during this period contained slightly more radium than did the raw water; at Farmington the reverse situation occurred. During the

late summer of 1959, 1 year later, it may be seen that the average radium concentration in filter sands at the Aztec plant was only $1.4 \mu\text{c}/\text{g}$, which is essentially background radium, and the radium concentration of the treated water was slightly lower than that of the raw water. On further investigation, it was learned that during July or August 1959, for reasons entirely apart from problems of contamination,

natural background radium concentration. This contamination of the filter sands was reflected in slightly higher dissolved-radium concentrations in the treated water supply.

Several conclusions may be drawn from this information. In the first place, radioactive pollution from the uranium mill was traceable directly to the water supplies. It is clear from the data that a conventional treatment

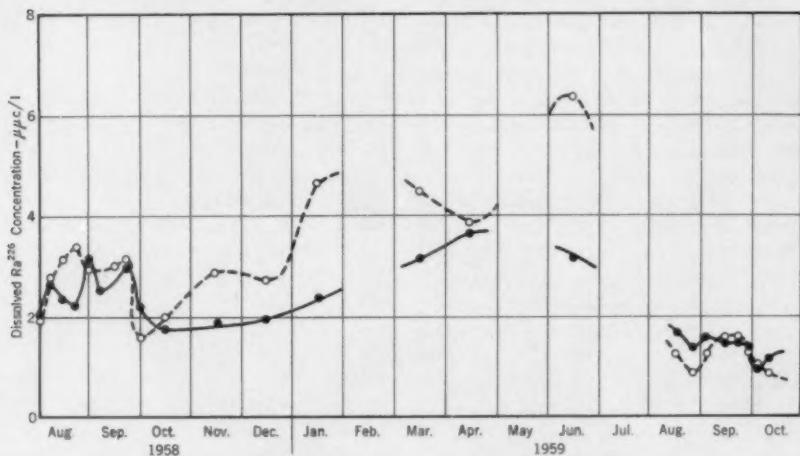


Fig. 5. DISSOLVED-RADIUM CONCENTRATIONS IN FARMINGTON WATER

Solid curves represent treated water; dashed curves, raw water. It is evident that conventional treatment, without water softening, did not dependably remove radium from the water.

the filter sands at the Aztec plant were discarded and replaced with clean sand. Because remedial measures at the mill were in effect by this time, and the spring floods had passed, no further significant contamination of these filter sands occurred. At Farmington, on the other hand, during late 1959, the average radium concentration in filter sands was $6.7 \mu\text{c}/\text{g}$, or approximately five to six times the

plant cannot be expected to remove dissolved radium at these low concentrations, at least not without water softening. Secondly, the pollution abatement measures installed at the uranium mill resulted in markedly reduced Ra^{226} concentrations in the downstream water supplies. Thirdly, the effects on the water supplies of discharge of radium-bearing spent ore solids into the river are evident. Some

of these solids find their way into the water treatment system—specifically, into the filter sands—and can constitute in the sand filters a reservoir of Ra²²⁶ which slowly dissolves into the treated water and contaminates it. This pertains again to the importance of knowing the fate of radioactive materials in the water environment before standards are set and discharge into rivers is permitted. It points again also to the importance of reducing such environmental contamination to the lowest degree possible.

Pollution Abatement Measures

The environmental radioactivity surveys that yielded estimates of human radiation exposure along the Animas also provided the data required for the selection of the most beneficial and rational pollution abatement measures. These remedial measures were based on detailed knowledge of the effects of the mill effluents in the Animas River and on more general knowledge of their fate in the water environment, rather than on enforcement of arbitrary preset standards. As a result, it was possible to achieve a very high degree of radiologic protection of downstream water users, and yet to accomplish this in a rational, efficient, and, hence, economical fashion.

As soon as the facts from the environmental survey were available, agreement as to the desirable remedial measures was reached quickly. In brief, these measures included removal from the effluents, by sedimentation, substantially all radium-bearing ore solids, removal by chemical treatment of at least 70 per cent of the dissolved Ra²²⁶, and removal of the toxic chemicals that had in the past seriously in-

terfered with the development of a normal downstream aquatic population.

As has been shown, the river sediment reservoir of Ra²²⁶ had been the major cause of high concentrations of dissolved radium in the flowing water. This sediment contamination had resulted from a daily discharge of approximately 30 mc of Ra²²⁶ as suspended ore solids, and retainment of these solids at the mill to eliminate the sediment contamination was the most important remedial measure. Discharges of dissolved radium of approximately 0.5 mc/day were also to be reduced to no more than 0.15 mc/day. Thus, it could be predicted

TABLE 3
Ra²²⁶ Concentration in Filter Sands

Period	City	Avg Ra ²²⁶ Concentration μmc./g.
Aug.-Oct. 1958	Aztec	27
Aug.-Oct. 1958	Farmington	4.7
Aug.-Oct. 1959	Aztec	1.4
Aug.-Oct. 1959	Farmington	6.7

that, with these two measures fully established, and allowing for scouring of old Ra²²⁶ deposits by flood flows, the downstream dissolved-Ra²²⁶ concentrations should again approach natural background levels.

Sedimentation, treatment, and lagoon facilities were installed as quickly as possible, and, by late October 1959, the pollution abatement measures were generally in effect, except for the possibility of an occasional brief release during the initial operating period. An evaluation survey performed in November 1959 verified the immediate benefit of the pollution

abatement effort. As has been seen, dissolved-Ra²²⁶ concentrations at the downstream water plants were reduced at once by approximately 60 per cent. The Ra²²⁶ concentrations in river muds were only approximately 10-15 per cent of their former levels, and the dissolved-Ra²²⁶ concentration of river water at the Colorado-New Mexico boundary was reduced to approximately 20 per cent of its 1958 value. All these percentage reduction figures would be higher if they were measured against the levels observed on Apr. 4, 1959, instead of against the data of late summer 1958. By early October 1959, the dissolved-Ra²²⁶ concentrations in the raw water supplies at Aztec and Farmington had dropped to 1.0 $\mu\text{c}/\text{l}$ or less, or well below the recommended limit of 3.3 $\mu\text{c}/\text{l}$.⁴ Details of these improvement figures and computations are given elsewhere.⁶

Some relatively slight residual contamination of river mud deposits and filter sands at Farmington remained in November 1959. With the gradual dispersal of the contamination during the winter months and the flushing action of the spring 1960 floods, and on the assumption that no significant new releases occur at the mill, it can be predicted that dissolved-Ra²²⁶ concentrations in the raw and treated water supplies at Aztec and Farmington should decrease by the late summer of 1960 to approximately 0.5 $\mu\text{c}/\text{l}$. This value is only about twice the natural background Ra²²⁶ concentration of Animas River water. As far as radium is concerned, the total human internal radiation exposure of downstream populations will have then been reduced well below the recommended limit for general populations, and quite close to levels that would

exist if the uranium mill were not present.

The foregoing rational approach to radioactive waste control has resulted in the installation of reasonable, economical pollution abatement measures and a degree of protection for the downstream water user that is not achieved by the enforcement of arbitrary standards. Such studies of the fate of radioactive materials in the water environment point to the best feasible pollution abatement techniques.

Public Information

During the 2 months following the release of the report of detailed results of the Animas River studies, a certain amount of public concern and apprehension regarding radiation exposure developed in the Durango-Farmington area. Public concern about radiation exposure is becoming more frequent. Experience gained from the Animas River studies may be of assistance in preventing or minimizing public apprehension in the future.

The Animas River report⁵ was rather voluminous, and its distribution was limited. A total of 300 copies was distributed to various federal, state, and local agencies and to individuals requesting them. Various statements found their way into the public press, some factually correct but necessarily brief, and others only partially correct or incorrect. As such statements appeared, one after another, often contradicting one another, it is not surprising that the local populace became quite concerned.

Public concern, as evidenced, for example, by the local sale of bottled water advertised as unpolluted by uranium mill wastes, reached a peak about

2 months after the results were released and about 1 month after a conference at which it was agreed that pollution abatement measures would be installed at the mill immediately. Accordingly, at this time, a public meeting, arranged by the New Mexico Department of Public Health in Farmington, was attended by officials from all the federal, state, and local agencies involved. This meeting, except for brief opening remarks, was an informal question-and-answer session.

The essential facts were brought out quickly. It became clear that, for a relatively brief time, some individuals in the Animas River Valley had probably ingested somewhat more radium than the recommended limit would allow, *if the ingestion were to be continued for a lifetime*. It was also brought out that this exposure level was considerably lower than is considered allowable for the working population. It was shown that this happened in part because of the changing concepts of radiation protection and the recent tendency to make standards for protection of the general public more and more stringent. It was indicated especially that standards for public protection are based on a concept of a lifetime of exposure and that to exceed them slightly for a period of, say, 3 or 4 years, although definitely not desirable, does not mean that people will suffer detectable harm. Finally, the questions and answers brought out the facts that pollution abatement measures had been devised and would be installed within a matter of 2 or 3 months and that radiation exposure levels would be greatly reduced as a result.

Essentially no subsequent local expression of apprehension occurred

after this meeting. It appears from this case history that a single measure—making public the essential facts—might well have prevented or greatly minimized the development of local public apprehension. It is therefore suggested that, in problems involving environmental contamination by radioactive materials, pertinent factual information, together with necessary comment and interpretation, be released to the public by the agencies involved as quickly as such information becomes available. If this is done, the informed general public should not prove so susceptible to the apprehension that can result from too brief and, at times, incorrect statements of individuals.

Summary

Recent comprehensive studies of radioactive pollution of the Animas River by refinery wastes of uranium ore indicated that the total internal radiation exposure of downstream populations was greater than the limits recommended for general population exposure. Studies of the fate of Ra²²⁶, the primary pollutant, in the stream environment and in local water plants led to the development of rational, efficient pollution abatement measures. These measures were installed quickly, and subsequent surveys showed that they resulted in a much higher standard of radiation protection than would have been achieved by enforcement of preset, arbitrary effluent or stream standards.

During the months following the release of the reports of the studies, some local public apprehension developed. This apprehension could have been minimized by a more aggressive public information program.

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Environmental Radioactivity Prior to Nuclear Power Plant Operation

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Navnit C. Kothary**

A paper presented, in part, on Apr. 5, 1960, under the sponsorship of AWWA, at the Engineers Joint Council's Nuclear Engineering and Science Congress, New York, N.Y., by John V. Nehemias, Director, Radiological Health Surveys, National Sanitation Foundation; G. Hoyt Whipple, Assoc. Prof. of Radiological Health, School of Public Health; and Navnit C. Kothary, Radiochemist, Radiological Health Surveys, National Sanitation Foundation, all located at the Univ. of Michigan, Ann Arbor, Mich.

THE procedures and techniques employed in a preoperational survey of the radiologic environment of the Enrico Fermi atomic power plant near Monroe, Mich., and the results obtained in 1958 have been reported previously.¹ The results obtained in 1959, a comparison of these with the results obtained in 1958, and an outline of the modifications in the program will be summarized here.

The survey has been conducted for the Power Reactor Development Co., Detroit, Mich., by the National Sanitation Foundation (NSF), Ann Arbor, Mich. The data collected prior to routine operation of the reactor, scheduled to begin in 1961, provide basic information on the levels of radioactivity present in the environment and the kinds of variation to which these levels are subject. This information, in conjunction with continuing measurements of environmental radioactivity after routine operation has begun, should provide a sound basis for an evaluation of the impact of reactor operation on the radiologic environment.

All samples have been analyzed for gross beta activity. In addition, radiochemical procedures have been employed to provide a measure of the levels of specific radionuclides present in the environment. Particular emphasis here is on Sr⁹⁰. A sample has been examined with a gamma spectrometer in order to identify specific radionuclides by their characteristic gamma radiation energies.

Sample Collection

The 1959 sample collection program and the changes from the procedures used during 1958 will be discussed. Figure 1 shows the locations at which the samples were collected. Table 1 lists the number of samples of each medium collected at each location during 1959.

Surface water samples were collected at weekly intervals at each of seven locations. At five of these locations, daily samples were collected by cooperating agencies and combined into the weekly sample. Sampling was initiated during 1959 at Flat Rock and

Ann Arbor, Mich. Daily samples are collected by the staff at the Department of Agriculture's research station in Harrow, Ont., and combined into a monthly sample. This sampling procedure was also begun during 1959.

Ground water samples were collected weekly from a well situated at the reactor site, and monthly from each of two wells located within 5 mi of the site. One of these off-site wells is at

during 1959. Serious operating difficulties were encountered with the devices during the spring of 1959. A major overhaul was completed early in the summer. New piston-type pumps were installed, fittings were modified, and gages were incorporated to measure pressure drop across the filters and to activate a shutoff mechanism in the event of filter rupture. Since the completion of these modifica-

TABLE 1
Samples Collected at Each Location, 1959*

Medium	Sampling Point and Number of Samples																	Totals		
	Reactor Site		Monroe	Lake Erie†	Carlton	Swan Creek	2 Nearby Wells	Grossette Ile	Toledo	Harrow	Lake Erie‡	Huron River§	Belleville	Lake Erie#	Ann Arbor	Sandusky	Lake Erie**	Port Clinton††	Brighton††	
	Apples	Benthos	Cabbage	Dust	Earth	Fish	Grass	Aquatic plants	Juniper	Mammals	Milk	Plankton	Rain	Sediment	Ground water	Surface water				
Apples	5	4																	16	
Benthos	3	3																	48	
Cabbage	3	3																	21	
Dust	38	41																	190	
Earth	6	5	8																50	
Fish	6	5																	53	
Grass	6	7																	52	
Aquatic plants	5	6																	59	
Juniper	5	7																	51	
Mammals	4	5																	42	
Milk	5	7																	39	
Plankton	5	12	12	6	6	6			12	12	9	6	6	6	6	12	12	6	59	
Rain	12	12																	81	
Sediment	6																		60	
Ground water	46						23												69	
Surface water	51	52					52		52	52	8	15			49				331	
<i>Totals</i>	197	146	30	31	82	23	142	110	56	27	56	29	30	135	48	30	26	23	1,221	

* See Fig. 1. † Pointe aux Peaux. ‡ Colchester. § Flat Rock. || Ford Lake. # Bono. ** Pelee Island. †† Pond. ‡‡ Wolverine Lake.

the nearest populated area to the south of the site and one at the nearest populated area to the west.

Samples of total precipitation were collected at each of seven locations. At one of these, Harrow, sampling was initiated during 1959.

Continuous dust-collecting devices were in routine operation at each of six locations. Sampling was begun at Toledo, Ohio, and at Flat Rock, Mich.,

not a single sample has been lost because of failure of the collection device.

Terrestrial biota—including apples, cabbages, earth, grass, juniper, and field mice—were sampled at eight locations at a rate of seven times per year. Earth samples were placed in storage without treatment. Apples and cabbages were collected only during the months when the edible portions were

available. On several occasions, no sample of field mice could be obtained.

Aquatic biota—including benthos, fish, higher aquatic plants, plankton, and sediment—were sampled at ten locations at a rate of six times per year. Sediment samples were placed in storage without treatment. On some occasions, no samples of fish or benthos could be obtained. No samples of benthos were collected from Wolverine Lake at Brighton, Mich.

A monthly collection of milk samples at each of five locations was begun in 1959. Quart quantities of milk are purchased over the counter in the areas sampled. Representative dairies of the areas were selected after the matter was discussed with the local health authorities.

Sample Preparation

All samples were taken to the laboratory as soon as possible after collection. There, aliquots were taken from the samples and prepared for gross beta counting. These preparations consisted primarily in volume reduction by evaporation or dry ashing, whichever was appropriate for the particular sample.

The only new medium added to the program during 1959, milk, was subjected to both evaporation and ashing. A 10-ml aliquot was drawn from each sample and evaporated to dryness on a hot plate. The residue from this operation was then placed in a furnace at 550°C for 8 hr. The resulting fine, white ash was then washed into a stainless steel planchet with dilute nitric acid, dried, and counted.

Radioactivity Measurements

The amount of gross beta radioactivity, in thallium-equivalent microcuries per unit of weight or volume, was

evaluated, as in 1958, with a low-background, gas-flow Geiger counter. Late in 1959, preliminary investigations were conducted with a single-channel, automatic-stepwise-scanning gamma spectrometer, counting for 8 min on each of 100 channels. The 8-min counting time limited the sensitivity of this preliminary analysis but represented the maximum automatic-scanning time of the instrument. A scan of 0–1 Mev was performed on a grass sample. In this range, those



Fig. 1. Area Surrounding Enrico Fermi Atomic Plant

Shown are the locations at which samples were collected.

channels that contained significant numbers of counts (gross counts in excess of background by at least two standard deviations) were compared with possible fission product contaminants. In addition, longer counts were made at the individual channels corresponding to the gamma energies emitted by Na^{22} and Na^{24} .

The results of this preliminary analysis are shown in Table 2. The channels listed are those in which sig-

nificant radioactivity, as defined above, was observed. Where known fission products coincide with the observed maxima, these nuclides are listed, with the calculated total activity in that energy interval and the pertinent regulatory limit.^{2,3} It will be noted that none of the observed radioactivity levels exceeds the regulatory limit. For some of the more hazardous nuclides, such as I^{131} , the limit of detection with 8-min counts on this instrument would exceed the regulatory limit. With the use of a 200-channel analyzer, however, much longer counts are feasible, and the detection limit could be reduced to levels below the regulatory limits.

It should be pointed out that the net counts observed in any channel indicate radiation in that energy region absorbed by the detector. These counts may be caused by emissions in this energy region or by scattered and degraded photons originally emitted at higher energies. With complex spectra, such as might be expected from environmental samples, it will, in general, not be feasible to determine rigorously what portion of the counts observed in a particular channel were contributed by photons emitted at that energy. A calculated activity based on the total number of counts observed in a particular channel must be interpreted with this fact in mind. Activity calculated in this manner provides an upper limit on the amount of a specific nuclide that could be present in the sample.

For purposes of the present survey, the foregoing information should be sufficient, in most instances, to indicate that the nuclide in question is not present in excess of one-tenth the pertinent regulatory limit. If the total counts

observed in a particular channel indicate that a nuclide is present in excess of one-tenth its regulatory limit, two possible procedures may be followed: (1) correction can be made for counts caused by scattering from higher energy peaks or (2) the nuclide in question can be radiochemically separated to determine what portion of the observed counts were caused by emissions occurring in that channel.

TABLE 2
Gamma Spectrometric Analysis

Energy Interval kev	Radio-nuclide	Radioactivity Concentration $\mu\text{c}/\text{hr}$	0.1 MPC for Population* $\mu\text{c}/\text{hr}$
40-50	Rh ^{103m} †	5.3×10^{-7}	1×10^{-8}
50-60	—‡	2.7×10^{-7}	
80-90	Xe ¹³³	3.3×10^{-7}	4×10^{-8}
90-98	Nd ¹⁴⁷	1.3×10^{-6}	6×10^{-8}
148-158	Kr ^{85m} †	2.9×10^{-7}	
225-235	Te ¹²⁵	2.1×10^{-7}	2×10^{-8}
	Xe ^{133m} †		
365-375	—‡	3.4×10^{-7}	
510	Na ²²	3.9×10^{-7}	3×10^{-8}
1,280	Na ²²	3.8×10^{-7}	3×10^{-8}
1,380	Na ²⁴	7.3×10^{-7}	3×10^{-8}

* See References 2 and 3.

† The letter *m* on radionuclides indicates an isomeric state.

‡ No fission product nuclide in this energy interval.

Radiochemical Procedures

The radiochemical procedures used have been partially reported elsewhere.¹ Only the procedures new in 1959 are reported here. These include pretreatment of ground water, dust and milk, radiochemical separation of Y^{90} , further evaluation of Sr^{90} and Sr^{89} , and photometric determination of potassium content.

In 1959, the pretreatment procedures previously developed for barium and strontium analysis of surface water samples were applied to ground water samples. Addition of carrier elements

resulted in the formation of some precipitates, possibly barium and strontium sulfates, in samples of high mineral content. These precipitates were subjected to carbonate metathesis (boiling with sodium carbonate), which converted the sulfates into carbonates that could then be dissolved with dilute acids.

Dust samples were first subjected to specific radiochemical separation in 1959. Samples were leached vigorously with dilute acids (nitric or hydrochloric) in the presence of strontium and barium carriers. This procedure has been found to leach out approximately 90 per cent of the total gross beta radioactivity in the sample. The leachates were used in subsequent radiochemical separations.

Samples of milk, first collected in 1959, were ashed at 550°C until a fine, white ash was obtained. The resulting ash was then dissolved in dilute acid. The residual insoluble material was separated on a filter.* In all instances, the radioactivity in the insoluble material has been found to be only a small fraction of that in the soluble portion.

Specific Sr⁹⁰ analyses were first performed in 1959, with the use of a standard gravimetric procedure.* A preliminary separation of barium and strontium was performed. The separated strontium, in the form of soluble nitrates, was stored in the presence of yttrium carrier for 2 weeks. Yttrium was then precipitated as the hydroxide and as the oxalate and counted. The quantity of Sr⁹⁰ at equilibrium is identical to the amount of Y⁹⁰ activity. The quantity of Sr⁹⁰ in the sample can then be calculated as the difference

between total strontium activity and Sr⁹⁰ activity.

The commercial yttrium used as the carrier was found to contain significant amounts of long-lived radioactivity. It was therefore purified before use by the method of Fresco.* In this method, the yttrium is selectively extracted from the aqueous phase into tributyl phosphate and then extracted back to the aqueous phase. This technique reduces the level of contamination by a factor of approximately 100.

The amount of potassium in a sample has been determined with a flame photometer.† After this is done, the amount of radioactive potassium present can be calculated from the specific activity of natural potassium, 820 $\mu\text{c}/\text{g}$.⁸

Results of Survey

Yearly average radioactivity concentrations for each medium are shown in Table 3. The columns labeled "Confidence Interval" represent two standard errors. This quantity provides a measure of the variability of the observed radioactivity concentrations. Radioactivity concentrations are given in microcuries per gram, with the following exceptions: microcuries per milliliter for dust, surface water, milk, and ground water; and microcuries per square centimeter per day for rain.

Table 4 summarizes the radiochemical results by nuclide and medium, and compares the fractions of gross beta radioactivity observed in the specific radionuclide analyses with the fractions predicted if all the gross beta radioactivity were the result of fallout

* Membrane filter, made by Millipore Filter Corp., Watertown, Mass.

† Model 146, manufactured by Perkins-Elmer Corp., Norwalk, Conn.

of fission products produced in the fall of 1958.⁷

Figures 2, 3, and 4 are plots of the average radioactivity concentrations for water, dust, and rain, respectively, as a function of time. Also shown are the confidence intervals, as previously defined, indicated as the interval between the upper and lower curves.

other biota. The averages for 1959 tend to be slightly higher than the comparable values for 1958; the confidence intervals tend to be somewhat smaller.

Variations With Location

With the exception of surface water, no systematic differences in radio-

TABLE 3
Comparison of Average Concentrations of Radioactivity by Media, 1958-59

Medium	Avg Concentration—1958 $\mu\text{c/g} \times 10^{-6}$	Confidence Interval—1958 $\mu\text{c/g} \times 10^{-6}$	Avg Concentration—1959 $\mu\text{c/g} \times 10^{-6}$	Confidence Interval—1959 $\mu\text{c/g} \times 10^{-6}$
Grass	25.0	5.4	40.0	7.3
Juniper	22.0	4.7	32.0	7.9
Plankton	16.0	8.4	10.0	3.4
Aquatic plants	15.0	3.8	17.0	4.0
Cabbage	9.2	3.1	5.1	0.7
Earth	6.7	1.9		
Surface sediment	6.0	1.4		
Benthos	4.8	1.6	7.4	3.8
Mammals	3.6	0.73	6.5	1.8
Apples	2.6	1.1	8.2	7.0
Fish	2.5	0.41	2.9	0.3
Milk			1.2*	0.1*
	Avg Concentration—1958	Confidence Interval—1958	Avg Concentration—1959	Confidence Interval—1959
Rain— $\mu\text{c/sq cm}/\text{day} \times 10^{-6}$	10.0	3.0	7.7	2.2
Surface water— $\mu\text{c/ml} \times 10^{-6}$	2.7	0.91	2.6	0.4
Ground water— $\mu\text{c/ml} \times 10^{-6}$	0.87	0.24	0.8	0.1
Airborne dust— $\mu\text{c/ml} \times 10^{-12}$	8.8	4.9	7.9	2.1

* $\mu\text{c/ml} \times 10^{-6}$.

Variations With Media

The summary of yearly averages given in Table 3 indicates that the levels of radioactivity fall into three categories, each significantly different from the others: biota, water, and airborne dust. As in 1958, grass and juniper exhibited appreciably more radioactivity concentration than the

activity concentrations among locations were observed during the 2-year period. The differences in radioactivity in surface water observed in 1958 appear again in 1959. The activity levels in the reactor lagoon and in Swan Creek are significantly higher than those in Lake Erie, and the activity level in Trenton Channel is signifi-

cantly lower than that in Lake Erie. These differences presumably reflect real local differences in drainage and hydrologic and meteorologic conditions.

Variations With Time

Figure 2 illustrates the variation of gross beta radioactivity concentrations in surface water since the beginning of the survey. An upward trend occurred throughout 1958, continuing into the spring of 1959, during which period a maximum was reached. Throughout the remainder of 1959, a continuing downward trend was noted. Similar time variations were observed in studies of dust, grass, juniper, mammals, and rain.

This reversal in the trend from 1 year to the next implies rather clearly that the observed systematic increase throughout 1958 was attributable neither to a gradual approach to equilibrium with the environment nor to seasonal variation. The dominant factor affecting the 2-year data is apparently the rate of nuclear testing, which proceeded at an increasing rate during 1958 and was stopped completely in the fall of 1958. The fact that the maximum values were not observed until the spring of 1959, several months after the cessation of testing, suggests that the rate of transfer of radioactive material from the stratosphere into the troposphere is more rapid in the spring. It will be of interest to observe whether or not a similar maximum occurs in the spring of 1960.

The media that could be collected only during the growing season (apples, benthos, cabbage, fish, higher aquatic plants, and plankton) verified, in general, the existence of a common tendency toward increasing radioactiv-

ity concentrations in 1958 and toward decreasing concentrations in 1959. The range of values included within the confidence interval showed a general tendency to be somewhat smaller in 1959 than in 1958. This condition might reflect a reduction in the fluctuations caused by the meteorologic variations, inasmuch as proportion-

TABLE 4
*Radiochemical Analyses by Radionuclide
and Medium*

Radionuclide & Medium	No. of Samples Analyzed	No. of Positive Samples	Avg Percentage of Gross Beta Activity*
<i>Ba¹⁴⁰</i>			
Dust	2	0	
Juniper	1	0	
Milk	4	0	
Rain	8	0	
Water	20	0	
<i>Total Sr</i>			
Milk	1	0	
Rain	7	0	
Water	8	0	
<i>Sr⁹⁰</i>			
Dust	4	4	5.9
Fish	2	2	6.1
Grass	2	2	2.4
Milk	15	15	1.0
Rain	6	0	
Surface water	23	0	
Ground water	4	0	

* The calculated percentages of gross beta activity were: Ba¹⁴⁰ media, 0-8; total Sr media, 3-10; and Sr⁹⁰ media, 0-2.

ately less fallout radioactive material was being deposited during 1959.

Comparisons With Other Data

Governmental agencies are engaged in the collection and analysis of environmental samples for gross beta radioactivity concentrations in the same general area covered by the present survey. These agencies use meth-

ods of collection and processing that should render the data directly comparable. Cooperative effort has therefore been made not only to provide maximum independent coverage of the area but also to provide overlapping of procedures for direct comparisons

the Herman Kiefer Hospital in Detroit. Monthly averages of the resulting radioactivity data for 1959 are plotted in Fig. 3 and 4 for dust and rain, respectively, for direct comparison with the survey data. Confidence intervals are indicated as the vertical

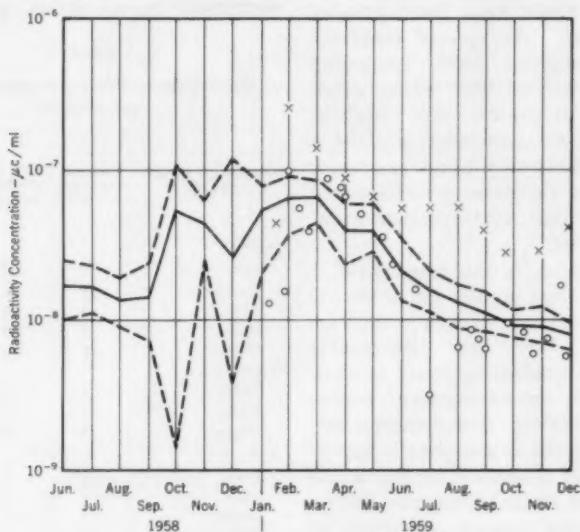


Fig. 2. Average Beta Radioactivity Concentrations in Water, 1958-59

Circles represent average data from the Water Resources Commission for Detroit, Flat Rock, Swan Creek, and Monroe, Mich. Cross marks represent average data from the Ohio Department of Health for Toledo. The solid curve connects the mean values of NSF data for each time period. The interval subtended by the dashed curves at each time period represents the confidence interval.

of results. Such cooperative programs have been undertaken with these agencies: Detroit Department of Health (dust and rain), Michigan Department of Health (dust), Ohio Department of Health (water), Michigan Water Resources Commission (water), and AEC (dust).

The Detroit Department of Health collects dust and rain on the roof of

separation between the upper and lower curves. Figure 3 shows that the data from the Detroit health department agree satisfactorily with the data from NSF, with the exception of the first few months of the year. As that was the period during which the most severe difficulties were encountered with the dust-collecting devices—primarily pump failures and leaking

fixtures—this result may provide some measure of the amount of radioactivity lost as a result of these machine failures. Figure 4 compares the rainfall data collected by the Detroit health department with those from NSF, and shows that the Detroit results are

community. A series of samples are being collected at Detroit for processing by NSF to determine whether the observed differences in radioactivity content of rainfall are the result of the heavy dust load in the area of the hospital.

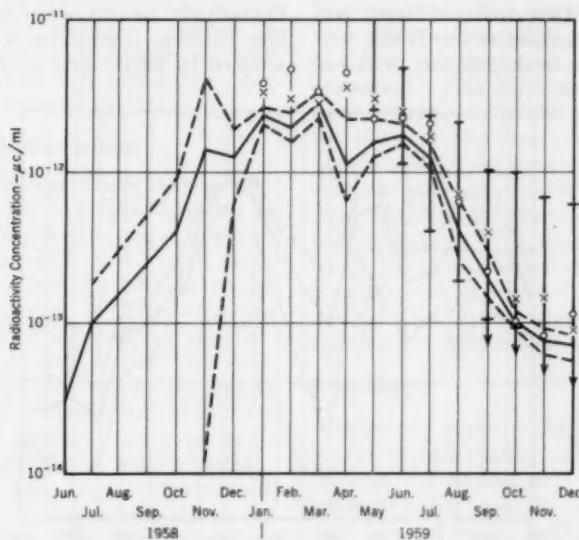


Fig. 3. Average Beta Radioactivity Concentrations in Airborne Dust, 1958-59

Circles represent average data from the Detroit Department of Health. Cross marks represent average data from the Michigan Department of Health for Carleton, Monroe, Rockwood, and the reactor site. Heavy, bounded vertical lines in the right portion of the figure show the range of values reported by AEC. Arrowheads are on ranges whose lower limits are less than 10^{-13} . The solid curve connects the mean values of NSF data for each time period. The interval subtended by the dashed curves at each time period represents the confidence interval.

significantly higher throughout. The rainfall collected at the Herman Kiefer Hospital is noticeably dirtier, more soot-laden, than any of the samples collected by NSF. The sampling locations used for the collection of rainfall by NSF are, for the most part, in fairly dust-free areas on the outskirts of the

The Michigan Department of Health collects dust samples continuously at the meteorologic tower on the reactor site, as well as at other locations in the general area covered by the present survey. The monthly averages of the radioactivity data from the department's 1959 samples from Carle-

ton, Monroe, Rockwood, and the reactor site are plotted in Fig. 3 for comparison with NSF data. As in the comparison with the data of the Detroit health department, satisfactory agreement is observed, with the exception of the first few months of the year.

The Ohio Department of Health collects water samples at the Toledo municipal water intake, as well as at nu-

an internal flow counter with a background counting rate of approximately 70 cpm. It is probable that, if 95 per cent confidence intervals were calculated for the Ohio health department data on Toledo, the apparent difference would not be significant.

The Michigan Water Resources Commission collects water samples at four locations comparable to locations sampled by NSF: Detroit, Flat Rock,

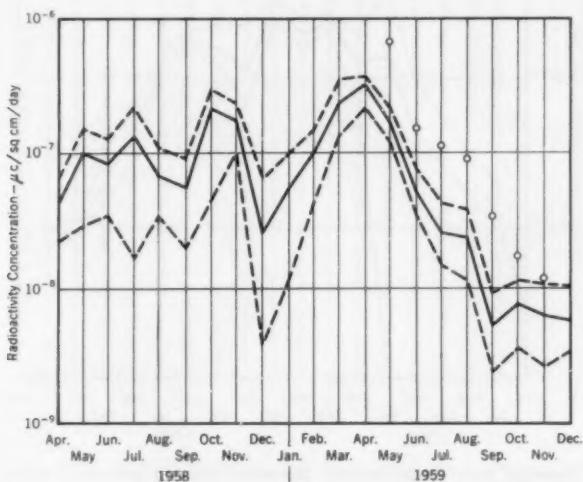


Fig. 4. Average Beta Radioactivity Concentrations in Rain, 1958-59

Circles represent average data from the Detroit Department of Health. The solid curve connects the mean values of NSF data for each time period. The interval subtended by the dashed curves at each time period represents the confidence interval.

merous other locations in Ohio. The monthly average radioactivity concentrations reported for the Toledo intake during 1959 are plotted in Fig. 2, for direct comparison with NSF data. The two time functions are seen to be in fairly good qualitative agreement, with the Ohio health department data consistently somewhat higher. The department uses 250-ml aliquots and

Swan Creek, and Monroe. The monthly average radioactivity concentrations at these four locations are plotted in Fig. 2 for comparison with NSF data. Good qualitative agreement is observed between the results of the commission and those of NSF. The greater variability in the values reported by the commission reflects the lower counting sensitivity because

of smaller aliquots and higher background counting rates.

AEC has reported⁸ ranges of values for radioactivity concentrations in airborne dust throughout the United States, beginning in May 1959. These ranges have been plotted in Fig. 3 for comparison with NSF data. With the exception of the May value, each of the monthly averages reported by NSF, as well as the 95 per cent confidence interval, lies within the range of values reported by AEC.

Specific Radionuclides

The amount of sample material processed for specific radioanalysis was selected to permit detection of quantities at least as small as one-tenth of the regulatory limit for effluent to uncontrolled areas.^{2,8} Under these conditions, in all 35 analyses for Ba¹⁴⁰ and in all 16 analyses for total strontium, as well as in all 33 analyses for Sr⁹⁰ in rain, surface water, and ground water, no significant quantities of the specific radionuclides were observed.

In fish, grass, and milk, quantities of Sr⁹⁰ in excess of the design detection limits— $5.0 \times 10^{-10} \mu\text{c}/\text{ml}$ (or $\mu\text{c}/\text{g}$)—were observed. In grass and milk, the fractions of the gross beta radioactivity attributable to Sr⁹⁰ are in the range predicted, assuming that most of the gross beta radioactivity was the result of fission products originating in the fall of 1958. In fish, a somewhat higher fraction was found, implying a concentrating mechanism, possibly in the formation of bones. The average concentration of Sr⁹⁰ found in milk by NSF was $1.3 \times 10^{-8} \mu\text{c}/\text{ml}$. This compares favorably with the 1959 average value reported by USPHS for Sr⁹⁰ in milk at Cincinnati⁹: $1.3 \times 10^{-8} \mu\text{c}/\text{ml}$.

It was convenient to use samples of dust much larger than the samples for most of the other media. As a result, concentrations substantially lower than the design detection limits could be measured.

Preliminary potassium analyses, performed with a flame photometer, have been reported. The calculated results seem unreasonably high as compared to those obtained by radioactivity evaluation. This discrepancy may reflect technical difficulties inherent in the complex chemical nature of the sample media. On the other hand, recent measurements of the decay constant of K⁴⁰ have demonstrated rather poor agreement.¹⁰ The range of uncertainty in these experimental values is sufficient to account for the observed discrepancies between photometric and radiologic determinations.

Summary

When any major nuclear production facility is planned, the possibility that radioactive materials may be inadvertently released into the environment must be considered. Evaluation of the impact of plant operation on the levels of radioactivity in the environment implies knowledge of radioactivity levels present before operation begins. A preoperational survey of environmental radioactivity has been in progress for 2 years in the vicinity of the power reactor being constructed in southeastern Michigan by the Power Reactor Development Co. Environmental radioactivity has demonstrated a general increase throughout 1958, continuing into the spring of 1959, and a general decrease thereafter throughout 1959. The results of this survey are given in greater detail in a report

by the National Sanitation Foundation to the Power Reactor Development Co.

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Effects of Phosphates on Coagulation and Sedimentation of Turbid Waters

—James J. Morgan and Richard S. Engelbrecht—

A paper presented on Mar. 17, 1960, at the Illinois Section Meeting, Chicago, Ill., by James J. Morgan, Instructor in San. Eng., and Richard S. Engelbrecht, Prof. of San. Eng., both of the Dept. of Civ. Eng., Univ. of Illinois, Urbana, Ill.

THE increased consumption of synthetic detergents in recent years has prompted research into the effects of these substances on conventional water treatment processes. Operational difficulties have been attributed to the presence of synthetic detergent compounds in treatment plant influents, and considerable research has been undertaken to establish what effects synthetic detergent components have on treatment processes, principally coagulation, sedimentation, and filtration. The major components of present-day commercial synthetic detergents are surface-active agents and builder compounds. The most important compounds among the builders are the condensed phosphates, sodium tripolyphosphate (STP), and tetrasodium pyrophosphate (TSPP).

Purpose of Investigation

The purpose of the investigation was to evaluate the effects of STP and TSPP on the clarification of hard, turbid water under conditions of continuous flow in a pilot-scale treatment plant. Previous articles have presented the results of an extensive survey of phosphate concentrations in Illinois surface waters.^{1, 2} The survey established that concentrations of maxi-

mum inorganic condensed phosphates in surface waters used as sources of water supply are generally less than 0.5 mg/l P_2O_5 , with, as previously reported, about half coming from land drainage sources. The results of laboratory jar test experiments on the effect of STP, TSPP, and orthophosphate on the coagulation of hard, turbid waters of the type employed in the present investigation have also been reported.³

Characteristics of Waters

The waters used during the investigation were hard waters, with characteristics of mineral quality reported in the survey of Illinois streams.² Two different sources of phosphate-free water were used during the pilot plant studies. Demineralized water, to which inorganic chemicals were added, was used for a number of pilot plant experiments. The addition of appropriate chemicals to the demineralized water produced a water with these mineral characteristics: alkalinity, 200 ppm; calcium hardness, 70 ppm; and total hardness, 300 ppm. For the remainder of the pilot plant experiments, a phosphate-free, local ground water was used. This water had the following mineral characteristics: alkalinity,

300 ppm; calcium hardness, 125 ppm; and total hardness, 250 ppm.

Powdered clays were added to these waters, and they were mixed for several hours in order to produce a raw-water turbidity of 50-120 ppm. A grain size distribution of the clays used indicated that particle size ranged from less than $1\text{ }\mu$ to approximately $10\text{ }\mu$.

Coagulants

The coagulants used were filter alum (technical-grade aluminum sulfate),

be of greatest importance among the condensed phosphate builders. The levels tested were chiefly 0.5 and 1.0 ppm P_2O_5 , because these were the upper limits most frequently observed in Illinois streams.

All phosphate concentrations have been expressed as parts per million P_2O_5 (1 ppm $\text{P}_2\text{O}_5 = 1.73$ ppm STP = 1.87 ppm TSPP = 1.34 ppm PO_4 = 0.43 ppm P). The method used for the determination of condensed phosphate and orthophosphate was based

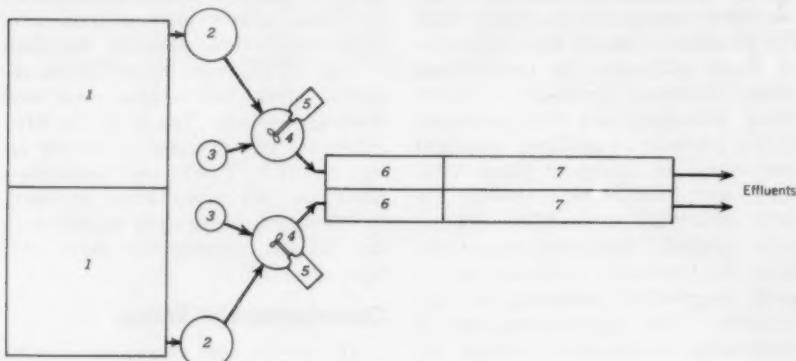


Fig. 1. Pilot Plant Treatment Units

The effects of the phosphate compounds on coagulation and sedimentation were measured with two identical treatment plants: 1, raw-water basins; 2, constant-head supply tanks; 3, chemical feeders; 4, rapid mixing tanks; 5, rapid mixers; 6, flocculation basins; and 7, sedimentation basins.

reagent grade ferric sulfate, and reagent grade ferric chloride. Dosages reported are the actual weights of these coagulants used.

Phosphate Compounds

The compounds tested were those known to constitute a major fraction of the builder compounds in household synthetic detergents. STP ($\text{Na}_5\text{P}_3\text{O}_{10}$) and TSPP ($\text{Na}_4\text{P}_2\text{O}_7$) are reported to

on the colorimetric measurement of orthophosphate. Acid hydrolysis was used to convert condensed hydrolyzable phosphate to orthophosphate.*

Turbidity Determinations

A spectrophotometer * was used for several experiments, but the majority

* Model 14 Coleman Universal spectrophotometer, made by Coleman Instruments, Maywood, Ill.

of the turbidity determinations was made with one type of turbidimeter.* Another turbidimeter,† was used for calibration purposes. Hardness, alkalinity, and pH determinations were made according to *Standard Methods*.⁸

Pilot Plant Studies

The effects of a given phosphate concentration on coagulation and sedimentation were determined by periodic sampling of influent and effluent waters during pilot plant experiments approximately 8 hr long. Each sample was analyzed for turbidity, and the effectiveness of turbidity removal for both the test phosphate water and the phosphate-free control water was determined. Comparison of removal efficiencies, accompanied by a statistical evaluation of the significance of their differences, indicated the effect of the phosphate compound on the process. Among the factors that exert an influence on turbidity removal are intensity of rapid chemical mixing, rate and time of flocculation, and settling time. These factors were varied during the investigation.

Apparatus. Two identical treatment plants were used to measure the effects of the phosphate compounds on coagulation. Each plant consisted of a raw-water basin, constant-head supply tank, chemical feeder, rapid mixing tank and equipment, flocculation basin, and sedimentation basin. The layout of the treatment units is shown in Fig. 1. The walls of the flocculation and sedimentation basins were of laminated glass ‡ construction to facilitate ob-

servations of floc size and settling characteristics. Figure 2 shows the apparatus in operation.

Each raw-water basin had a storage capacity of 680 gal. The capacity of the basins was selected to allow an experiment to last for as long as approximately 10 hr at a design flow rate of 1 gpm. A valve connected the two basins, and a circulating pump was provided for the purpose of completely mixing the contents of the two basins for a number of hours prior to each experiment. It was possible to mix thoroughly the contents of the basins and then to isolate each basin from the other prior to the addition of a phosphate compound to the water of one basin.

The chemical feeders were constant-rate solution feeders, each consisting of a constant-head siphon with a calibrated glass tip. The feeders added coagulant directly to the rapid mixing tanks, which provided a variable mixing period. The mixers were operated at speeds up to 1,000 rpm.

The flocculation and sedimentation basins were rectangular, each 12 ft long, 1 ft wide, and designed for a 2-ft flow depth. The first 4 ft of basin length contained the flocculation mechanism, which consisted of variable-speed oscillating flocculators. The flocculators consisted of metal dasher plates, which moved vertically through the flocculation zone. The calculated retention time in the flocculation zone was 1 hr at a flow rate of 1 gpm.

The final 8 ft of basin length constituted the sedimentation zone, which was separated from the flocculation zone by a hanging baffle. The calculated retention time was 2 hr at a flow rate of 1 gpm, and the design velocity was 0.067 fpm. The sedimentation

* Manufactured by Hellige, Garden City, N.Y.

† Jackson candle turbidimeter, supplied by E. H. Sargent & Co., Chicago, Ill.

‡ Plexiglas, made by Rohm & Haas Co., Philadelphia, Pa.

basins had a surface loading rate of 180 gpd/sq ft of surface area. The outlet device of each flocculation and sedimentation basin consisted of an 11-in. sharp-crested weir.

Short-circuit analysis. It is known that sedimentation basins may be short circuited, so that actual median

course of the pilot plant studies. According to Camp and Stein,⁶ the overall flocculation characteristics of a system may be represented by the product of G , the temporal mean velocity gradient, and T , the period of flocculation. G is a function of the power input (P) for flocculation, the viscos-

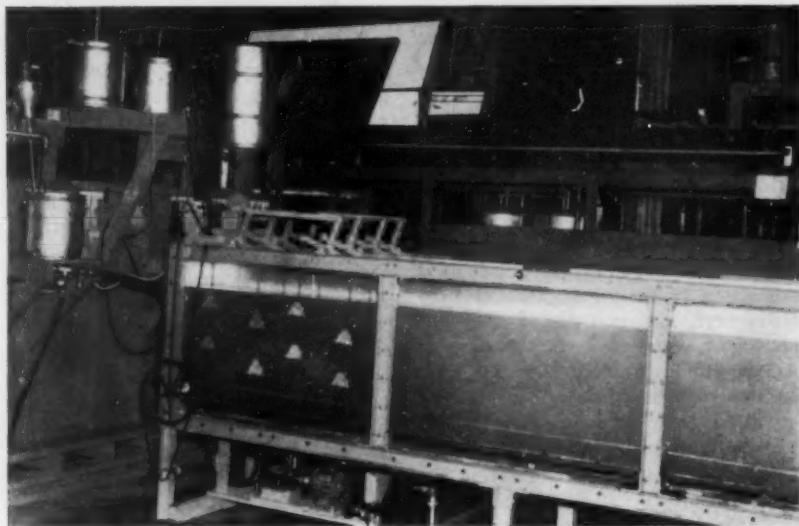


Fig. 2. Pilot Plant in Operation

Shown are some of the treatment units diagramed in Fig. 1: raw-water basin, chemical feeder, mixing tank, and flocculation and sedimentation basins.

periods of flow are less than calculated retention periods. A short-circuit analysis conducted in the units at a flow rate of 1 gpm yielded a median flow-through period of 110 min., as compared to the calculated period of 180 min. through the flocculation and sedimentation basins.

Flocculation characteristics. Both the speed of the oscillating flocculators and the calculated retention period of flocculation were varied during the

ity (μ) of the water, and the volume (V):

$$G = \sqrt{\frac{P}{V\mu}}$$

The dimensionless product GT is given in Table 1 for each of the flocculation conditions.

Procedures

Eight to fifteen determinations of influent and effluent turbidity were made on both the control and test

plants during each experiment. Turbidity determinations were made within 15 min of the time of collection. Observations of floc size and settling characteristics were noted. Concentrations of phosphate were determined by analysis to verify the calculated amount of phosphate compound added. Temperature measurements also were recorded during the course of each experiment.

In order to verify the identical performance of the two treatment plants, a series of experiments was made in which all conditions in both plants were either exactly the same or the reverse of those of a previous experiment. These experiments demonstrated that both plants performed identically.

After each experiment, all units were thoroughly cleaned with detergent-free water in preparation for the next experiment. Settled sludge was removed, the rapid sand filters were backwashed, and the raw-water storage tanks were washed and drained. The chemical feeding devices were calibrated prior to each experiment.

Experimental Results

The data of each experiment consisted of a number of turbidity determinations on influent and treated water. From these data, the average efficiencies of turbidity removal were computed, and from this information, the ratio of the efficiency of turbidity removal of the test water to that of the control water was calculated. This ratio is representative of the magnitude of interference with normal coagulation. A value approaching unity indicates slight or no interference; lower values indicate greater interference. The significance of the differ-

ence between the average control and average test efficiencies for each experiment was analyzed with the use of the "Table of *t*" from Table IV of Fisher.⁷ The number of experiments in each series which showed a significant difference between test and control efficiencies are noted in Tables 2-7. Of the 37 experiments reported, 29 showed a significant difference in efficiencies. Not all experiments, however, were made under the same conditions, as will be noted later. Of the eight experiments remaining, one experiment could be considered to show a significant difference at a 90 per cent confidence limit; seven ex-

TABLE 1
Flocculation Characteristics of Pilot Plant

Paddle Velocity fpm	Theoretical Time min	Calculated <i>G</i> /sec	Calculated <i>GT</i>
2.0	60	0.89	3,200
2.9	60	1.6	5,750
4.7	60	3.2	11,500
4.7	120	3.2	23,100

periments showed no interference effects.

Alum Coagulation

Results for alum coagulation of hard, turbid water in the presence of condensed phosphates are shown in Tables 2-5. The results shown in Tables 2-4 demonstrate that increased concentrations of STP and TSPP increase the magnitude of interference with coagulation. It is also indicated that an increase in the coagulant dose is capable of decreasing this interference. The results of Tables 2 and 3 were obtained without rapid mixing and at flocculation speeds of 2.0-2.9

TABLE 2

Alum Coagulation in the Presence of Relatively High Concentrations of STP in Hard, Turbid Water†*

Experiment‡	Temperature °C	Coagulant Concen- tration ppm	Phosphate Concen- tration ppm P_2O_5	Avg Efficiency-%		Efficiency Ratio	Final Turbidity ppm	
				Control	Test		Control	Test
1	20	32	1.1	84.6	78.9	0.93	16.6	25.4
2	21	63	2.2	87.7	82.7	0.94	14.2	22.8
3	19	63	4.5	86.4	79.9	0.92	22.4	40.1
4	19	63	6.7	81.4	70.1	0.86	15.6	22.4

* In previous work,^{1,2} condensed phosphate concentrations in Illinois surface waters were found to be generally less than 0.5 ppm P_2O_5 .

† The conditions of the test were: calcium hardness, 70 ppm; total hardness, 300 ppm; alkalinity, 200 ppm; flocculation speed, 2.0 fpm; flocculation-sedimentation time, 3 hr; and no rapid mixing.

‡ All experiments showed a significant difference between control and test waters at a probability of 0.05, by statistical analysis.

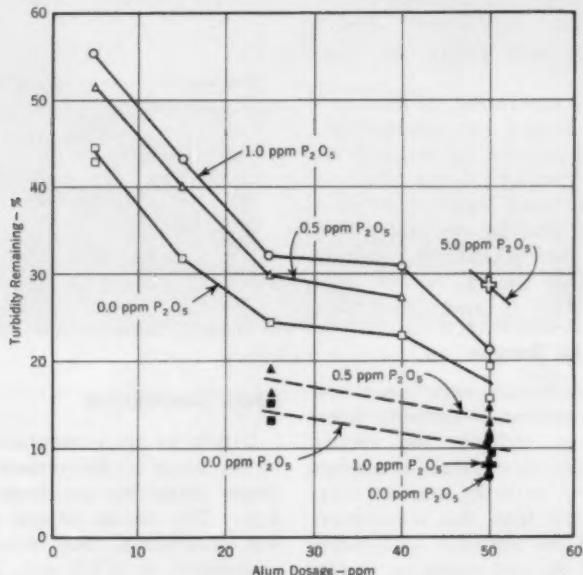


Fig. 3. Relationship of Turbidity Remaining and Alum Dosage Under Various Conditions and Condensed-Phosphate Levels

Open symbols joining solid curves represent the following test conditions: no rapid mixing; mixing rate, 2.9 fpm; and settling time, 2 hr. Solid squares and triangles joining dashed curves represent these conditions: rapid mixing; mixing rate, 2.9 fpm; and settling time, 2 hr. The solid circle and cross mark represent these conditions: rapid mixing; mixing rate, 4.7 fpm; and settling time, 4 hr.

fpm. It is to be noted that, under these conditions, the lowest efficiency ratio obtained was 0.80 (Table 3, Experiment 5). This result was obtained for a condensed phosphate level of 1.0 ppm P_2O_5 at an alum dosage of 5 ppm. For the same alum dosage, but at a condensed phosphate level of 0.5 ppm P_2O_5 , the efficiency ratio was 0.85 (Table 3, Experiment 1).

The addition of rapid mixing to the treatment process appeared to promote

coagulation was increased to 4.7 fpm and the calculated retention time was increased to 6 hr. Under these conditions, coagulation of waters containing STP or TSPP levels of 1 ppm P_2O_5 resulted in elimination of essentially all interference (Experiments 1 and 3). The results of Experiment 2 showed the orthophosphate compound, monosodium phosphate, to produce no interference. At the rather high STP level of 2.0 ppm P_2O_5 , an efficiency

TABLE 3
*Alum Coagulation in the Presence of TSPP in Hard, Turbid Water**

Experiment†	Temperature °C	Coagulant Concen- tration ppm	Phosphate Concen- tration ppm P_2O_5	Avg Efficiency-%		Efficiency Ratio	Final Turbidity ppm	
				Control	Test		Control	Test
1	22	5	0.5	57.0	48.6	0.85	35.7	40.5
2	21	15	0.5	68.2	59.8	0.88	28.9	34.1
3	24	25	0.5	75.5	70.1	0.93	20.1	27.6
4	21	40	0.5	77.2	72.4	0.94	23.6	26.2
5	23	5	1.0	55.6	44.6	0.80	55.2	44.6
6	23	15	1.0	68.2	56.8	0.83	31.9	34.6
7	22	25	1.0	75.5	68.4	0.91	24.3	32.2
8	23	40	1.0	77.2	69.1	0.90	22.1	27.9
9	23	50	1.0	84.2	78.7	0.94	14.5	22.7
10	22	70	1.0	73.9	70.5	0.96	27.3	30.4
11	23	70	1.0	78.5	74.9	0.95	24.3	28.9
12	22	70	2.0	83.8	77.2	0.92	14.5	18.6
13	21	50	5.0	80.4	72.1	0.90	19.7	29.7

* The conditions of the test were: calcium hardness, 70 ppm; total hardness, 300 ppm; alkalinity, 200 ppm; flocculation speed, 2.9 fpm; flocculation-sedimentation time, 3 hr; and no rapid mixing.

† All experiments showed a significant difference between control and test waters at a probability of 0.05, by statistical analysis.

coagulation and thus reduced the moderate interfering effects of the condensed phosphate (Table 4). The lowest efficiency ratio in Table 4 is 0.94 for a TSPP level of 1.0 ppm P_2O_5 and a coagulant dosage of 50 ppm alum. A comparison of Experiments 5 and 6 in Table 4 indicates that STP and TSPP have about equal interfering effects on alum coagulation.

Table 5 shows results obtained with alum coagulation when the rate of flo-

ratio of 0.97 was obtained with 25 ppm alum (Experiment 4).

Figure 3 shows the turbidity results for the alum coagulation experiments reported in Tables 2-5. Percentage of turbidity remaining is plotted against alum dosage. The adverse effects of increased levels of condensed phosphate may be noted, as well as the increased turbidity removals obtained by increasing the alum dosage. Figure 4 shows the effect of condensed phos-

TABLE 4
Alum Coagulation in the Presence of TSPP and STP in Hard, Turbid Water*

Experiment†	Temperature °C	Coagulant Concentration ppm	Phosphate Concentration ppm P_2O_5	Avg Efficiency-%		Efficiency Ratio	Final Turbidity ppm	
				Control	Test		Control	Test
1	25	25	0.5	84.5	81.4	0.96	15.2	18.5
2	26	25	0.5	86.9	84.0	0.96	12.6	14.1
3	26	50	0.5	90.0	87.5	0.97	10.8	12.7
4	24	50	0.5	89.4	85.5	0.96	11.0	14.2
5	26	50	0.5‡	89.9	86.6	0.96	9.6	12.7
6	23	50	0.5‡	90.8	87.8	0.97	5.9	8.0
7	25	50	1.0	90.3	85.8	0.95	9.7	14.3
8	24	50	1.0	89.2	83.9	0.94	12.0	16.3

* The conditions of the test were: calcium hardness, 70 ppm; total hardness, 300 ppm; alkalinity, 200 ppm; rapid mixing, 500 rpm; flocculation speed, 2.9 fpm; and flocculation-sedimentation time, 3 hr.

† All runs, with the exception of Experiment 1, showed a significant difference between control and test waters at a probability of 0.05, by statistical analysis. Experiment 1 may be thought of as having a significant difference at a probability of 0.10.

‡ STP.

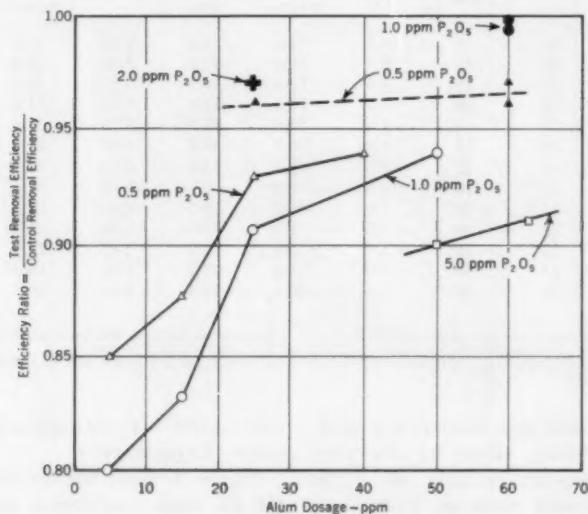


Fig. 4. Relationship of Efficiency Ratio and Alum Dosage Under Various Conditions and Condensed-Phosphate Levels

Open symbols joining solid curves represent the following test conditions: no rapid mixing; mixing rate, 2.9 fpm; and settling time, 2 hr. Solid triangles represent these conditions: rapid mixing; mixing rate, 2.9 fpm; and settling time, 2 hr. The solid cross mark and circles represent these conditions: rapid mixing; mixing rate, 4.7 fpm; and settling time, 4 hr.

phate on turbid-water clarification, in terms of the efficiency ratios obtained at various coagulant dosages. The beneficial effects of improved mixing and flocculation and increased settling times are reflected in higher values of the efficiency ratio under these conditions.

Ferric Chloride

Table 6 shows the data obtained in two pilot plant experiments in which ferric chloride was used as a coagulant.

calculated retention time. Comparison of Experiments 4 and 5 again shows the approximately equal effects of STP and TSPP on the process.

Discussion of Results

The first AWWA task group report on synthetic detergents⁸ summarized several reported instances of water coagulation difficulty attributed to synthetic detergents. Laboratory studies by Smith,⁹ Howells,¹⁰ Langelier,¹¹ and their associates indicated

TABLE 5
*Alum Coagulation in the Presence of STP, TSPP, and Orthophosphate
in Hard, Turbid Water**

Experiment†	Temperature °C	Coagulant Concen- tration ppm	Phosphate Concen- tration ppm P ₂ O ₅	Avg Efficiency-%		Efficiency Ratio	Final Turbidity ppm	
				Control	Test		Control	Test
1	27	50	1.0‡	91.6	91.1	0.994	5.2	5.5
2	26	50	1.0‡	91.3	92.6	1.000	5.8	5.0
3	28	50	—	91.6	91.2	0.996	4.1	4.3
4	24	25	2.0‡	88.0	85.6	0.970	7.7	9.2

* The conditions of the test were: calcium hardness, 125 ppm; total hardness, 250 ppm; alkalinity, 300 ppm; rapid mixing, 500 rpm; flocculation speed, 4.7 fpm²; and flocculation-sedimentation time, 6 hr.

† Only Experiment 4 showed a significant difference between control and test waters at a probability of 0.05, by statistical analysis.

‡ STP.

|| Monosodium phosphate, as P₂O₅.

|| 1 ppm TSPP, 1 ppm monosodium phosphate, as P₂O₅.

The results correspond to those obtained with alum.

Ferric Sulfate

Results obtained with ferric sulfate as a coagulant are shown in Table 7. Experiments 1 and 2 indicate successful coagulation of waters containing STP and TSPP levels of 0.5 ppm P₂O₅ with a ferric sulfate dosage of 50 ppm. The effect of increased retention time on interferences is seen by comparing Experiments 3 and 4, in which the efficiency ratio was increased from 0.94 to almost 1 by doubling the

that the surface-active components of household synthetic detergents did not produce significant interference with coagulation at concentrations of less than 15–20 ppm, but that interferences were caused by the condensed phosphate builder compounds, STP and TSPP.

Previous studies² conducted at the University of Illinois indicated that the ABS concentration of sewage effluents is approximately 2–5 ppm, and that ABS concentrations in streams receiving sewage discharge are generally less than 1 ppm. These data agree with

those obtained for the Neosho River at Chanute, Kan.¹² Apparently, ABS levels are not so high as to produce adverse effects on the coagulation process. Reports of interferences by condensed phosphates, however, indicated that an investigation of these compounds was required.

The stream studies at the University of Illinois,^{1, 2} referred to before, showed that condensed phosphate concentrations were generally less than 0.1 ppm P_2O_5 in lakes and reservoirs, and generally less than 0.5 ppm P_2O_5 in streams receiving significant domestic sewage. They also showed that about

as an efficiency ratio, which is the ratio of turbidity removal efficiency for a water with phosphate to that of a control water without phosphate. For condensed phosphate levels of 0.5 ppm P_2O_5 —exceeded only about 10 per cent of the time—the interference ratio ranged from 0.85, under conditions of low coagulant dosage and poor flocculation conditions, to 0.999, under conditions of increased coagulant dosage and improved flocculation. For condensed phosphate levels of 1.0 ppm P_2O_5 , which might be expected to occur less than 3-5 per cent of the time in Illinois surface waters,² effi-

TABLE 6
*Ferric Chloride Coagulation in the Presence of TSPP in Hard, Turbid Water**

Experiment†	Tempera- ture °C	Coagulant Concen- tration ppm	Phosphate Concen- tration ppm P_2O_5	Avg Efficiency—%		Efficiency Ratio	Final Turbidity‡ ppm	
				Control	Test		Control	Test
1	23	25	0.5	75.8	68.7	0.91	25.6	25.5
2	23	50	0.5	83.2	80.7	0.97	16.0	17.6

* The conditions of the test were: calcium hardness, 70 ppm; total hardness, 300 ppm; alkalinity, 200 ppm; flocculation speed, 2.9 lpm; flocculation-sedimentation time, 3 hr; and no rapid mixing.

† Both experiments showed a significant difference between control and test waters at a probability of 0.05, by statistical analysis.

‡ The initial turbidity values were considerably different for both of these experiments.

one-half of stream phosphates came from land drainage.

The results of this investigation show that condensed phosphates (STP and TSPP) at relatively high concentrations are capable of producing moderate interference with the coagulation and sedimentation of hard, turbid waters under operating conditions of continuous flow in a pilot treatment plant. The degree of interference at a given condensed phosphate concentration was reduced by a moderately increased concentration of coagulant. The degree of interference is expressed

efficiency ratios were in the range of 0.80-0.994, under the same range of conditions mentioned before. These results are in general agreement with those of Langelier,¹¹ Smith,⁹ Dietz,³ Howells,¹⁰ Cohen,¹⁸ and their associates. All these results were obtained with laboratory jar tests.

In view of the results of this investigation, it cannot be concluded that the condensed phosphate levels currently prevailing in surface waters are capable of producing troublesome interferences with coagulation and sedimentation of turbid waters. Investigations

reported to date indicate that, even when phosphate concentrations are unusually high, satisfactory operation can be obtained if reasonable increases in coagulant dosage are made. It is interesting to observe that although synthetic detergent usage has increased by about 50 per cent since 1954,¹⁴ there have been no significant reports of extreme difficulties with treatment attributed to synthetic detergents since that time.

Alum and iron salts appear to have approximately the same effectiveness in overcoming interferences by condensed phosphates. Orthophosphate compounds, such as monosodium orthophosphate, produce no interference with normal coagulation and sedimentation.

For condensed phosphate concentrations representative of those presently found in Illinois water supplies, 0.5 ppm P_2O_5 , the ratio of turbidity re-

TABLE 7
*Ferric Sulfate Coagulation in the Presence of STP and TSPP in Hard, Turbid Water**

Experiment†	Temperature °C	Flocculation-Sedimentation Time hr	Coagulant Concentration ppm	Phosphate Concentration ppm P_2O_5	Avg Efficiency-%		Efficiency Ratio	Final Turbidity ppm	
					Control	Test		Control	Test
1	27	3	50	0.5‡	86.9	86.8	0.999	8.1	8.2
2	26	6	50	0.5§	93.1	93.0	0.999	4.2	4.2
3	26	3	50	1.0‡	88.8	83.5	0.940	7.0	10.0
4	30	6	50	1.0‡	94.4	94.2	0.998	3.5	3.6
5	24	6	50	1.2§	90.4	89.1	0.986	5.7	6.4
6	27	6	50	2.0§	92.7	89.5	0.970	4.5	6.4

* The conditions of the test were: calcium hardness, 125 ppm; total hardness, 250 ppm; alkalinity, 300 ppm; rapid mixing, 500 rpm; flocculation speed, 4.7 rpm; and flocculation-sedimentation, as noted.

† Only Experiments 3 and 6 showed a significant difference between control and test waters at a probability of 0.05, by statistical analysis.

‡ STP.

§ TSPP.

Summary

From controlled experiments employing a pilot water treatment plant, it has been found that the condensed phosphate builder compounds, STP and TSPP, in relatively high concentrations, are capable of interfering with the coagulation and sedimentation of hard, turbid waters. The effects of TSPP and STP appear to be equal. The magnitude of the interference is reduced by reasonable increases in the coagulant dosage, improvement of mixing and flocculation characteristics, and by an increase in settling time.

removal efficiency in the water with phosphate to that obtained in a water without phosphate ranged from 0.85 to 0.99, depending on coagulant concentration, flocculation characteristics, and sedimentation time. At 1.0 ppm P_2O_5 , the corresponding ratios ranged from 0.80 to 0.94. From previous work, it has been found that levels of this magnitude could be expected to occur less than 3-5 per cent of the time in Illinois streams.

The results of this investigation, which are in agreement with those reported by others, support the conclu-

sion that troublesome interferences with coagulation and sedimentation of hard, turbid waters should not be caused by the condensed phosphate levels currently prevalent in water supplies.

Acknowledgment

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Purposes of Artificial Recharge

Task Group Report

The first in a series of reports on technical aspects of artificial ground water recharge by Task Group 2440 R—Artificial Ground Water Recharge, submitted by John J. Baffa (Chairman), Cons. Engr., New York, N.Y. Other members of the task group are H. C. Barksdale, C. M. Bechert, M. L. Brashears, C. R. Compton, F. B. Laverty, L. B. Losee, A M Rawn, L. F. Warrick, and W. F. Welsch.

The task group expects to continue the series as time permits and, eventually, to present the reports as a manual on artificial recharge.

ARTIFICIAL recharge may be defined as the practice of increasing, by artificial means, the amount of water that enters a ground water reservoir.¹ The purposes of artificial recharge discussed herein are those concerned with water supply problems only, although artificial recharge has application in waste disposal, secondary oil recovery, and land subsidence problems.

The need for artificial recharge has been brought about by an increasing demand for ground water as a source of fresh water. In certain areas throughout the world, the withdrawal of ground water has exceeded the natural recharge. The specific purposes for which artificial recharge is practiced are to:

1. Conserve and dispose of runoff and flood waters
2. Supplement the quantity of ground water available
3. Reduce or eliminate the decline in the water level of ground water reservoirs
4. Reduce, prevent, or correct salt water intrusion
5. Store water to reduce costs of pumping and piping

6. Store clear, cool water in winter for use during the summer
7. Allow heat exchange by diffusion through the ground
8. Obtain suspended-solids removal by filtration through the ground.

An artificial recharge installation may serve more than one purpose. In certain areas, for example, artificial recharge not only adds water to the available subsurface supply but also is a means of disposing of storm water runoff. In another instance, artificial recharge to bar salt water is also greatly increasing the available supply of fresh water and alleviating a ground subsidence condition that has been in progress for years. To illustrate each purpose of recharge, an example of an operating or experimental installation made for that purpose will be discussed briefly.

Conservation and Disposal

Artificial recharge for water conservation and flood control has been important in Southern California since about 1895.² In the Santa Clara Water Conservation District's project, situated in the Santa Clara River Valley in California, flood waters are

stored behind dams and released slowly, so that the water is absorbed in stream beds and off-channel ponds. Also, water is spread over receptive orchard land.¹ Thus, water that would otherwise be largely wasted in this semiarid region is conserved by storage in the ground and is available to meet water requirements. In addition, a degree of control of flood waters is obtained. Similar installations are in operation at other locations.

Supplementation of Ground Water

The Duhernal Water Co., situated along the South River near Old Bridge, N.J., supplemented the available ground water from its well field by impounding water behind a dam constructed in 1930 across a stream. Thus, by spreading water and increasing the head of water over the outcropping sands, the natural recharge of ground water was supplemented. Later, low-level dams constructed across small feeder streams further increased the area over which water was spread.

Water Level Decline

The most significant artificial recharge operations in the eastern United States are being carried out at numerous locations on Long Island, N.Y., particularly in Nassau County. Because of its rapidly increasing population and industrial growth, Long Island recognized the need to protect and conserve its sources of fresh-water supplies at an early date. At first, definite steps were taken to prevent pollution and contamination of the streams.²

Because of the increasing transition from an agricultural to an urban use of land, the runoff from storm waters greatly increased. Instead of percolating into the ground, vast quantities of

runoff water were wasted to tidewaters through storm sewers. The increasing demand for water and the decreasing quantity of water percolating into the ground were causing declining ground water levels that, if unabated, would result in serious salt water intrusion, which was occurring in the populous Brooklyn area at the western end of Long Island. Since 1933, the New York State Water Power and Control Commission (now Water Resources Commission) has required that water pumped from new wells and used for cooling and air-conditioning be returned to the aquifer from which it was withdrawn.

In 1936, Nassau County developed, and since that time has actively pursued, a long-range water conservation program. Under this program, the use of recharge basins has resulted in the return to the ground of large quantities of storm water which otherwise would have been wasted to tidewater.³ The application of artificial-recharge methods on Long Island has made a major contribution to the maintenance of the ground water level.

Salt Water Intrusion

As a result of ground water overdevelopment, extensive damage caused by sea water intrusion has already occurred in numerous ground water basins adjacent to the coast of California.⁴ A comprehensive investigational program was initiated in 1951 to determine the criteria for the control and prevention of sea water intrusion. This program included a large-scale investigation of the feasibility, with regard to hydraulics, of creating a pressure ridge in confined aquifers by means of injection wells, using fresh water, and the effectiveness of such a ridge in preventing sea water intrusion. One conclusion was that direct

recharge or maintenance of a fresh-water ridge above sea level may be a method to prevent or abate sea water intrusion, depending on geologic and hydrologic conditions and on the cost and quality of available supplemental water supplies for recharge.³

Cost Reductions

At Amarillo, Tex., large water storage facilities close to the city are needed to supply peak demands. An investigation indicated that it is feasible to recharge a well field near the city limits from a well field several miles away.⁴ Underground storage space is available in the aquifer because of a decline in the level of the water table.

Pumping the distant wells throughout the year at a fairly constant, but lower than maximum, rate would supply the city's winter demands and provide a surplus to be stored in the well field near the city. Summer demands in excess of the pipeline capacity from the distant fields would be met by pumping stored water from the nearby field. Thus, the pipeline to the new, distant well fields would be smaller than would be necessary if the lines were to meet peak seasonal water demands. Other advantages of underground storage as compared to surface storage are: (1) no losses by evaporation, (2) virtually no construction cost in preparing the reservoir for storage, and (3) utilization of equipment at the distant well fields, which otherwise would stand idle during the winter months.⁴

Seasonal Use

Cool ground water is used by the distilleries in Louisville, Ky. Increased industrial growth in the vicinity of the distilleries during World War II placed an additional demand

on ground water, resulting in a lowering of the water table. In order to provide adequate cooling water for summer use, the distilleries recharged the aquifer through their wells with clarified river water purchased from the city during the winter months, when the river water was cold. Then they withdrew water from the wells when the temperature of the river water was too warm.

Heat Exchange by Diffusion

Although the New York State requirement of recharging to the ground the well water used for cooling and air conditioning pertains to conservation of water, it is practical over a long period of time because the heat picked up by the water during its use is dissipated by diffusion through the ground. The degree to which the heat is dissipated depends on the distance it travels before it is pumped again.

On Long Island, the temperature of recharged cooling water is 2°–20°F higher than that of the water pumped from the ground. This recharged water has raised the ground water temperature appreciably in recharge centers; but where wells are not closely spaced or are separated by impervious layers, there has been no serious rise in temperature.¹

Suspended-Solids Removal

Recharge from induced filtration by pumping of wells located near surface sources is one example of suspended-solids removal by filtration through the ground. An armament plant located near Charleston, Ind., on the Ohio River, needed large quantities of water, a sizable amount of which had to be clear water. Investigation showed that the glacial outwash sands and gravels underlying the land terrace along the river were hydraulically connected

with the river, from which large quantities of water could be drawn by pumping water from the glacial materials. Consequently, several radial collectors * were installed. Not only was this an economical method to obtain the needed water, but also the water came out clear, because the turbidity in the river water was removed by the sands in the bottom of the river. In addition, the temperature of the water did not reach as high or as low a level as that of the river, and the concentration of dissolved solids in the water was more constant than that of the river. Also the bacteriologic quality of the water was improved, so that only a nominal dosage of chlorine was necessary to insure its use for drinking purposes.

Summary and Conclusions

Artificial recharge, where applicable, serves several valuable purposes that aid in solving water supply problems. It is an important method of storing runoff and flood waters, which otherwise would be wasted, for use when needed during dry seasons when streamflows are low. It provides a means of reducing or eliminating the deleterious effects of overdevelopment of ground water sources of supply, or it can be a means of supplementing an existing ground water supply. The other purposes of artificial recharge mentioned before—obtaining clear, cool water, for example—are less important, because other economical methods are available for these purposes. For example, clear water can be produced from surface waters by established treatment methods, and water can be cooled by refrigeration. But the first five purposes mentioned for artificial recharge are of primary im-

portance, because the surface streamflows in sections of the arid western states may be essentially nonexistent during dry seasons. Ground water is the only available source of supply, unless water is transported from great distances. Even in the eastern states, where rainfall is more plentiful, surface sources may be inadequate in heavy centers of population and industry, especially during periods of drought.

Although artificial recharge is a potential means of solving some water supply problems, each application must be evaluated to determine if it is physically and economically feasible. The geologic and hydrologic conditions that may affect the recharge must be evaluated at each location where artificial recharge is to be used. Also, the recharge water must be analyzed to determine its adequacy—that is, to determine whether it is chemically compatible with the ground water and whether it requires pretreatment to avoid the clogging of the soil. In addition, the most suitable method of recharge for the application must be selected and its cost determined.

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* Made by Ranney Method Water Supplies, Columbus, Ohio.

Innovations in Water Clarification

—Walter R. Conley and Raymond W. Pitman—

A contribution to the Journal by Walter R. Conley, Engr., and Raymond W. Pitman, Specialist, both of the General Electric Co., Richland, Wash.

WATER filtration research and development have been conducted by General Electric Co., Richland, Wash., with a small experimental filter plant at Hanford, Wash.¹ The results of the research have been utilized in operations with the Hanford reactors.

Among the objectives of water treatment is the removal of: (1) turbidity, (2) harmful bacteria and other organisms, (3) color, (4) taste and odor, and (5) iron and manganese. Removal of the first two is the most common and will be discussed here.

Turbidity and Bacteria Removal

Perhaps the most obvious objective of filter plant operation is the removal of turbidity from raw water. There are at least two reasons for removing the turbidity. First, the consumer will complain about having to drink muddy water. Second, because turbidity and various harmful organisms usually occur together in surface water, removal of turbidity usually removes most of the harmful organisms. These organisms are usually charged negatively, as is the turbidity, and can be coagulated and filtered, as can the turbidity.

There is good cause for stating that turbidity removal is the best criterion of overall filter plant performance. This index of performance is being

used at very few filter plants, probably because of the supposed technical difficulty of measuring turbidity with the required sensitivity and speed.

Filter Plant Control

Filter plant operation consists of coagulant addition, mixing, flocculation, settling, filtration, and chlorination. Efficient operation is an art dependent on the judgment and experience of the operating personnel. Operations at Hanford have been improved by the measurement of the quality of the end product quickly and as continuously as possible, and by the utilization of this information to control the variables that affect the quality.

A number of problems had to be solved before a rational control system was developed. An index of quality had to be selected which could be applied with the required sensitivity and speed. Such an index must permit rapid use, in minutes rather than in hours or days. The only index that seemed to be pertinent to the process—an index that measures the finished filtered water quickly—is a turbidity analysis. This was the index selected.

Successful control of the quality of the finished filtered water results in a number of advantages. Operating costs can be reduced, and the effect of such variables as flow rates can be evaluated objectively. Finally, much

of the operation can be reduced to a logical systematic method adaptable for easy job instruction. Personnel can be trained easier, quicker, and more effectively. It is believed that an effective control method has been developed at Hanford. After approximately 4 years of experimentation, the results of the method have been thoroughly evaluated and have been judged to be both practical and extremely useful for plants similar to that at Hanford.

Turbidity Measurement

As far as is known, there is only one instrument that has the necessary characteristics for adequate measurement of filtered-water turbidity for filter plant control purposes. This instrument is a modified, light-scattering microphotometer.^{2,3} It is durable, sensitive, easy to operate, fast working, and its results are reproducible. The instrument can detect substantial amounts of turbidity in the best grades of distilled water. Such sensitivity is of extreme importance in the rapid evaluation of filter media and the coagulation process, because very small differences in filtered-water turbidity can be used to establish a basic understanding of filter behavior under a variety of coagulation conditions. Data are obtained which can be used to predict the effect of changing variables on the performance of the overall process. The instrument very easily detects differences in the turbidity of filtered water produced by filter media of different sizes. Differences caused by changes in coagulation are detected with even greater sensitivity.

High-Rate Treatment

High-rate treatment refers to a flow rate that is two to four times the

standard design rate through each component of a plant, such as mixers, flocculators, settling basins, and filters. An increase in unit rates through the plant components can be achieved either by a redesign of the equipment to give better performance or by improved chemical treatment and control. From extensive experience at Hanford, it is concluded that very high flow rates through all of the standard filter plant components can be achieved by proper chemical treatment and control, without substantial plant modification.

Savings

Enough has been learned to state with considerable confidence that application of the proper chemical control methods and proper kind of filter media will make it possible for most filter plants to increase their water production with no sacrifice in water quality. This can be done at a fraction of the cost of any other known method of increasing plant capacity. Adequate chemical control with a light-scattering microphotometer can probably be justified from the savings in operating costs alone for any plant with a capacity larger than 5 mgd. Savings in chemicals should pay for the equipment of a 5-mgd plant in about 5 years. For larger plants, the equipment will be paid for even more quickly—in approximately 1 year for a 25-mgd plant.

Filter Conditioning

Coagulated matter usually adheres tenaciously to the surfaces of filter materials, but it can be broken loose from the filter grains. High-flow rates will often dislodge the particles, especially when the water is fairly viscous, at temperatures less than 10°C. This dislodgement of particles from filter

grains has been observed in plants throughout the country for many years; it is usually called breakthrough. Breakthrough results in turbid filtered water. It can be controlled by the addition of chemicals that will cause the floc particles to adhere more tenaciously to the filter grains. Activated silica and various organic coagulant aids used for the primary purpose of improving settling rates also have the property of causing the floc particles to adhere more tenaciously to filter grains.

At the Hanford experimental filter plant, it has been determined that various materials can be applied directly to the filters in such a manner as to cause floc particles to adhere to the filter grains very tenaciously. This process is called filter conditioning.⁸ Breakthrough is essentially eliminated by filter conditioning even at filtration rates as high as 10-15 gpm/sq ft and at settling times as short as 3 min. Unfortunately, breakthrough is eliminated at the expense of a faster rate of filter plugging than would otherwise occur. But, by varying the type and size of filter media and the chemical control methods, a process was worked out which is a considerable improvement over any other known process for producing exceptionally clear water at filtration rates of 5-10 gpm/sq ft with very short flocculating and settling times.

Two of the most effective filter conditioner chemicals* tested so far give effective results in concentrations of 0.005-0.05 ppm, at a cost of approximately 5-40 cents per million gallons

of water filtered. These chemicals are dissolved to give a 0.5 per cent solution and then fed continuously into the water entering the filter. It is essential that the chemicals not have time or be sufficiently agitated to be adsorbed by the floc particles. The chemicals may be added to a common flume feeding a bank of filters, but they must not be added at the flocculators. Agitation and time decrease their effectiveness.

It can be postulated that the organic chemicals act to bind the floc particles to the filter grains and to each other. The bonded material is easily removed by normal backwash procedures. After 3 years of experience, no evidence has been found of mudball formation or other adverse effects in the filter beds.

Control of the filter conditioner feed in a logical manner is essential. This is done by measuring the turbidity of the filtered water on filters near the end of the backwash cycle. If the samples contain turbidity, the rate of feed of the filter conditioner chemical is too low and should be increased. If the feed is increased too much, the filter head loss will increase rapidly. It is essential to find the proper balance between the favorable effect of the chemical on water clarity and the unfavorable effect on filter head loss. This can be done easily after a little experience with the process.

Typical data from the experimental plant for easy treatment conditions are shown in Table 1. Data for difficult treatment conditions are shown in Table 2. It can be seen from the tables that optimum chemical treatment is much more important than the size of the filter sand. It should be noted that satisfactory results cannot be obtained when the filter sand is too coarse, re-

* Separan NP-10, potable-water grade, made by Dow Chemical Co., Midland, Mich., and Hagan Coagulant Aid 2, a product of Hagan Corp., Pittsburgh, Pa. Both products have been approved for domestic water treatment by USPHS.

ardless of the chemical treatment used. It should also be noted that the filtration rate was very high, 10 gpm/sq ft.

The turbidity values shown in the last column of Tables 1 and 2 are not detectable with a standard Baylis turbidimeter and would all be reported as 0 ppm, except for the 0.03 and 0.05 values, which might be detected. A good grade of distilled water usually has a turbidity of approximately 0.02 ppm and often a turbidity as high as 0.05 ppm.

For simplicity, the data were presented for a filter made of sand only.

TABLE 1
*Typical Data for Easy Treatment Conditions**

Size of Filter Sand US Sieve†	Turbidity of Filtered Water—ppm		
	Insufficient Alum	Optimum Alum	Optimum Alum & Filter Conditioning
20-30	0.20	0.05	0.03
30-40	0.15	0.02	0.005
40-50	0.10	0.01	0.003
50-60	0.08	0.005	0.002

* Filtration rate, 10 gpm/sq ft; settling time, 1 hr; raw-water turbidity, 10 ppm; and raw-water temperature, 5°C.

† Passing-retained sizes are shown.

The effects of a filter on the quality of water remain unchanged when anthracite is placed on top of the sand. The rate of head loss change, however, is markedly affected by the addition of variable amounts of anthracite of variable sizes.

Optimum high-rate treatment for plants similar to that at Hanford is dependent on three factors: type of anthracite-sand filters, rate of filter conditioner feed, and sensitivity of measurements of filtered-water turbidity as a guide to operations. A defi-

ciency in any one of these factors will result in failure to achieve optimum results.

Chemical Treatment and Control

It has been recognized for many years that the use of coarse filter media makes it possible to increase filtration rates. Two objections, however, have been made to the use of coarse media. First, the media allow some turbidity to pass through into the filtered water. Second, the raw water must be coagulated and settled more efficiently to permit the use of the coarse media.

The trend in modern design of filters is to provide prolonged flocculation and settling facilities in order to permit the use of coarse filter media at rates of 3-4 gpm/sq ft. Capital cost savings with modern filters are small, because the money saved on the filters is spent on the extra flocculation and settling facilities. Suitable chemical treatment and control make it possible to take a different approach that results in large capital savings, moderate savings in operating costs, and improved filtered-water quality. This treatment, however, is not effective unless the proper kind of filter is used. The filter must not clog rapidly, even at high rates. Such a filter, however, may pass coagulated matter at high filtration rates when the water is cold, unless proper countermeasures are taken. The most effective countermeasure is to feed in the proper amount of filter conditioner chemical. Too much chemical will result in unnecessarily high rates of filter clogging. Too little chemical will not be effective in stopping the coagulated matter from passing through the filter. It is essential that the proper balance be found between the lowest clogging rate and

the best quality of filtered water. This balance cannot be found by the conventional method of conducting jar tests. One cannot predict filter-clogging rates from the appearance of floc. Also, the tendency of floc to break through a filter bed cannot be predicted from floc tests. Data on filter-clogging rates and breakthrough tendencies must be obtained by filtration studies.

In general, two distinct kinds of turbidity are present in filtered water. The first kind is caused by insufficient alum feed and consists essentially of

TABLE 2
*Typical Data for Difficult Treatment Conditions**

Size of Filter Sand US Sieve†	Turbidity of Filtered Water—ppm		
	Insufficient Alum	Optimum Alum	Optimum Alum and Filter Conditioning
20-30	>1	>1	0.05
30-40	>1	>1	0.008
40-50	>1	>1	0.005
50-60	>1	0.5	0.003

* All treatment conditions were the same as those for Table 1, except that the turbidity of the raw water was 500 ppm.

† Passing = retained sizes are shown.

uncoagulated particles. The second kind is caused by shearing forces within the filter and consists essentially of small pieces of coagulated matter. The two kinds of particles usually can be distinguished by use of the light-scattering microphotometer. The uncoagulated particles occur in greatest number just after a filter has been placed on the line following backwash. After 1-2 hr, only a few of these particles will be present in the water, unless the alum feed is too low. For this reason, a turbidity sample taken from a filter after 1 hr of opera-

tion is an excellent indicator for alum feed control. Consistently high turbidity readings on samples taken after 1 hr indicate that the alum feed is too low and that uncoagulated matter is passing through the filter.

Coagulated particles occur in greatest numbers in the filter effluent after several hours of operation. These particles break loose from the surfaces of the filter media because of the shearing force exerted by cold (viscous) water. Anything that increases the shearing force will tend to increase the particles in the effluent water. Unfavorable factors are increased water viscosity, high rate of flow in the filter, and a high ratio of pounds of coagulated material to square feet of filter surface. Within limits, the unfavorable factors may be counteracted by proper chemical treatment.

The general rule is to maintain the rate of alum feed as low as possible and the rate of filter conditioner feed as high as possible, in order to minimize the amount of coagulated matter in filtered water. The rate of alum feed must not be reduced so low as to cause uncoagulated matter to appear in the filtered water, as determined by turbidity checks on 1-hr filter samples. The rate of filter conditioner feed must not be increased so high as to cause rapid clogging of the filters. A proper balance must be found among filter-clogging rates, uncoagulated matter, and coagulated matter in the filter effluent. Laboratory filter tests are helpful during rapidly changing raw-water conditions to give a first estimate of the proper alum feed. During periods when raw-water conditions are stable, the laboratory filter tests need not be used to determine the rate of chemical feed. Instead, the feed can be regulated on the basis of turbidity

data from the plant filters. Two examples of regulation of chemical feed may help to clarify the procedures involved.

Example 1. Routine samples from filters that have been on the line for 1 hr show a turbidity of 0.1 ppm. Samples taken just before backwash after 30 hr show a turbidity of 0.05 ppm. This pattern indicates that the alum feed is too low, and, accordingly, the alum feed is increased. After enough time is allowed for the change in feed to take effect, new samples are taken. The 1-hr samples show a turbidity of 0.02 ppm; the end-of-run samples show a turbidity of 0.01 ppm. This pattern indicates that the rate of alum feed is high enough and that the filter conditioner feed is adequate.

Example 2. Routine 1-hr samples show a turbidity of 0.01 ppm; the end-of-run samples show a turbidity of 0.3 ppm. Duration of filter runs is 30 hr. The concentration of filter conditioner feed is 0.01 ppm; concentration of alum feed is 10 ppm. This pattern shows that filter runs are too long or that the rate of filter conditioner feed is too low. The first course of action is to reduce filter runs to 20 hr. After this change, the end-of-run samples show 0.1 ppm turbidity, while the filter head loss is only 4 ft. This information indicates that the concentration of filter conditioner should be increased. The concentration of filter conditioner is increased from 0.01 ppm to 0.03 ppm. After this change, the end-of-run samples show 0.01 ppm turbidity, but the head loss is 10 ft. The concentration of filter conditioner feed is reduced to 0.02 ppm as a final adjustment. The final end-of-run turbidity is 0.01 ppm, and the head loss is 8 ft.

As will be noted, this regulation of chemical feed is based on the principle that rate of alum feed controls the concentration of uncoagulated matter in the effluent water, and rate of filter conditioner feed controls the concentration of coagulated matter. A secondary principle is that the beneficial effects of the filter conditioner on water quality must be balanced against the detrimental effect of the chemical on filter head loss.

Filter Media

In order to realize optimum performance with high-rate filtration, it

TABLE 3
*Performance of Special Filter Made of 0.4-mm Sand and 1.0-mm Anthracite**

Condition of Raw Water	Turbidity of Filtered Water ppm	Length of Run hr	Filter Performance Index gal/ft head loss/sq ft
Cold, high turbidity	0.005	8	580
Warm, low turbidity	0.003	36	2,600

* Treatment conditions: flocculation time, 10 min; settling time, 1 hr; and filtration rate, 6 gpm/sq ft.

is extremely important to have filters loaded with special materials. If the filter material is too coarse, water quality will be impaired. The trend in the design of modern filters is to use as filter materials sand 0.6-0.7 mm in effective size or anthracite coal 0.7-0.8 mm in effective size. Both these materials, when used alone, allow significant amounts of suspended matter to pass through into the filtered water when the water is cold and when flow rates are high.

After testing hundreds of different kinds of filters, it is concluded that

filters made of both sand and anthracite of the proper sizes are markedly superior to filters made of any one single material.³ A filter made of 8 in. of 0.4-mm sand and 22 in. of 0.9-1.5-mm anthracite is believed to be exceptionally well suited for high-rate filtration. Head loss is low, and water quality is excellent with this filter. Typical data on sand-anthracite filters, when optimum amounts of alum and filter conditioner were used, are shown in Table 3. If it is agreed that filtered-water turbidity must be kept less than 0.01 ppm for all raw-water conditions at a filtration rate of 6 gpm/sq ft or more, then a filter made of sand and anthracite is believed to be essential.

Limitations of Study

The experimental work described here was done with Columbia River water. Other kinds of water may give different results. The purpose of the study was to support the operation of large-scale plants that are required to produce very clear water at high filtration rates and low operating costs. Some of the methods developed for Hanford may not be useful for small plants or for plants operating with low filtration rates. For large plants in need of increasing filtration rates, the Hanford methods are believed to be generally useful.

All of the work has been in direct support of water plant operation and is therefore mostly practical and empirical in nature. Basic research on the physical chemistry of the process has not been attempted.

Summary

A 5-gpm experimental filter plant has been operated for approximately 4 years. Useful data on chemical treatment and filter materials have been obtained. The principal achievements from the use of the plant are improved water filters, improved chemical treatment methods, and a demonstration of practical filtration with a flocculation time as short as 10 min, a settling time as short as 60 min, and a filtration rate as high as 10 gpm/sq ft.

An improved chemical treatment method was developed which uses 5-50 ppb of organic polyelectrolytes to control filter breakthrough. This treatment, used in conjunction with filters made of both 0.4-mm sand and 0.9-1.5-mm anthracite, makes it possible to filter water at very high rates without excessive head loss. The resulting filtered water is exceptionally clear, with less than 0.01 ppm turbidity. Results obtained in the experimental filter plant have been confirmed in large-scale filtration plants.¹

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Significance and Removal of Manganese in Water Supplies

Attmore E. Griffin

A paper presented on May 16, 1960, at the Annual Conference, Bal Harbour, Fla., by Attmore E. Griffin, Staff Consultant, Equipment Div., Wallace & Tiernan Inc., Newark, N.J., and Chairman, Task Group 2680 P—Manganese Deposition in Pipelines.

THIS article is based on data accumulated by AWWA Task Group 2680 P—Manganese Deposition in Pipelines, under the chairmanship of the author.

Manganese is a common ingredient of impounded water¹ and of many well waters. In public supplies, it causes such difficulties as staining of clothes and plumbing fixtures, "black" water, incrustation of mains, and interferences with the colorimetric chlorine residual test. In industrial supplies, it causes severe economic losses through discoloration of products, specks in finished goods, and reduction of pipeline carrying capacities.

The earth's crust consists of approximately 0.1 per cent manganese distributed quite evenly throughout. Plants have the ability to extract and utilize it in their metabolism. It finds its way into water by chemical and biologic processes.² Chemical reactions are generally presumed to account for the greater part of the manganese in ground water; in stored water, manganese builds up by a combination of biologic and chemical processes working simultaneously.

It is difficult to obtain clear-cut statements about the economic significance of manganese in water supplies. In spite of this, requests increase

yearly for information on how to remove manganese, how much the process will cost, and what method will best suit a specific water supply. The demand for answers to these questions is one indication that the presence of manganese in water is receiving wide attention.

Presence of Manganese

That biologic activity is a powerful factor in dissolving manganese is evidenced by the general lack of manganese in running streams where the water is of normal pH and alkalinity for the region. Once the water in the stream is impounded, however, manganese is almost certain to appear. In some areas, it will rise to measurable quantities within a year of impoundment; in other areas, 10 years may be required. Some evidence exists that the amount of plant life and the character of the soil inundated will influence the extent to which the dissolving of manganese will proceed. There are indications that in northern areas where plant growth is less lush and of shorter duration than in the warmer areas, less manganese will dissolve in impounded water. As an example, the manganese concentration at the bottom of the Wanaque Reservoir in northern New Jersey seldom exceeds 2.0 ppm,

whereas as much as 20 ppm or more has been found in some of the lakes of the Tennessee Valley Authority.

Manganese in river water is almost invariably associated with iron mine drainage, bottom water discharge from reservoirs, lakes, or marshes, and industrial pollution. There is little evidence that undammed rivers dissolve or leach manganese from the river bed unless the flow of water is very slow, such as in pools where biologic activity may be relatively great.

From New Jersey southward along the Atlantic seaboard to Florida, then westward along the Gulf of Mexico, up the Rio Grande, and into California, most new reservoirs develop manganese problems soon after being placed in service. Manganese in well water seems to be very prevalent in the states west of the Mississippi River and east of the Rocky Mountains from the Gulf of Mexico to the Canadian border.⁸ Manganese-bearing wells, however, are found all over the country.

Reporting of Manganese

Traditionally, manganese has been reported as a combination of iron and manganese, regardless of their ratio. The limit for an acceptable quality water has been 0.3 ppm iron and manganese. Generally speaking, this is a reasonable level for iron alone, but if the reported figure of 0.3 ppm should happen to consist mostly of manganese, severe difficulties could ensue. Some water utility men believe that water delivered to consumers should be completely devoid of manganese. For some industries, this is imperative. For the average domestic supply, however, it is quite possible that 0.01-0.02 ppm manganese could be tolerated.

Consideration is being given to separate reporting of iron and manganese.

Limits have not yet been established. The most frequently quoted limits are 0.30 ppm for iron and 0.02 ppm for manganese.

Manganese-Removing Organisms

The organisms that remove iron and manganese from water are currently being studied by R. S. Wolfe⁴ of the University of Illinois, Urbana, Ill. His studies are far from complete, but he has made available certain information that he considers to be basic. During the past year, he obtained a slime sample from a water system in Indiana which consisted of an almost pure culture of iron or manganese bacteria. These were hairlike bacteria growing in a sheath. They have extremely large cells for bacteria, measuring approximately $2 \times 10-20 \mu$.

It is interesting to note that the water in which these organisms were growing contained almost undetectable concentrations of iron and no detectable manganese. In spite of this, when the organism was washed and dried, approximately 28 per cent of its dry weight was found to consist of iron and manganese, in a ratio (Fe/Mn) of 0.9. It was further pointed out by Wolfe that these ensheathed or stalked bacteria do not need high concentrations of nutrient in the water but can extract their requirements from the large volumes of low-nutrient water passing them. This suggests that the presence of such organisms may possibly be more sensitive indicators of iron and manganese than chemical tests performed on limited volume samples.

Manganese Determination

F. I. Brownley⁵ of Clemson College, Clemson, S.C., has made a study for Task Group 2680 P of the various

methods used for determining manganese. As part of this work, he developed a new method that has not yet been either field tested or published.

There are indications that tests to differentiate between dissolved and suspended manganese would be useful where manganese is a problem. Some thought has been given to this phase of manganese determination, but the work is not far enough advanced for conclusions to be made. Oxidation-reduction potential measurements are being studied, and some work is being done toward the development of new methods for the separate determination of dissolved and suspended manganese.

Filter Media

When manganese manganese is oxidized in a water treatment plant, some manganese will usually reach the filters where it will be removed, except in those instances where the pH of the water is increased to more than 9.0. The suspended manganese will be caught on the surface of the media, and most of it will be removed when the filters are washed. Continued application of manganese-bearing water causes the sand grains to become black, and complete removal is not usually accomplished until this takes place. This is generally known as "aging" or "seasoning." If this black coating contains iron in addition to manganese, its color may be that of dark mahogany. If slimes are present, the whole surface will look ragged and, in all probability, the media should be cleaned. But if the grains of media are jet black and there is little evidence of bacterial growth, frequent cleaning may not be necessary and may even be detrimental.

Little information is available regarding sand grain growth resulting

from deposition of manganese dioxide. At the request of Task Group 2680 P, D. L. Erickson of Lincoln, Neb., made a series of such tests,⁶ the results of which are shown in Table 1. Although it may seem that the increase in sand grain size was quite considerable, filtration has apparently not been seriously impaired at Lincoln, because wholesale sand replacement or acid washing for removal of the deposit has not yet been necessary.

Manganese Stabilization

Manganese stabilization⁷ has not been widely publicized, but there are enough municipal and industrial plants (approximately 40) using this process

TABLE 1

*Thickness of Manganese Dioxide Coating on Filter Sand Grains at Lincoln, Neb.**

Filter Number	First Year of Operation	Avg MnO ₂ Thickness μ
2	1954	50
3	1937	338
7	1949	223
12	1958	58

* Analysis made in February 1959.

successfully to show that it is a practical method for eliminating "red" and "black" water. Stabilization is accomplished by adding glassy phosphate. The normal dosage is 2.0 ppm for each part per million of manganese present, with a minimum dosage of 2.0 ppm. This same ratio holds for iron. If the iron and manganese are reported together, the same ratio of 2:1 holds for the total figure shown in the analysis.

It is known that glassy phosphate, even though it is added ahead of an oxidizing agent such as chlorine, does not prevent the oxidation of iron; it

is assumed that the same holds true for manganese. Nevertheless, when glassy phosphate is used, it forms a colorless iron or manganese complex that, even after oxidation, is dispersed as a colloid and therefore is not noticeable.

The point of feed to stabilize manganese does not seem to be as critical as it is for iron. With iron, the phosphate must be added ahead of aeration or chlorination. In contrast to this, several instances have been recorded showing that phosphate has been added to the filtered water for manganese stabilization even though the water had been previously aerated and coagulated.

Unlimited amounts of manganese can be stabilized with glassy phosphate. Economically, however, its use is somewhat limited. The larger plants can seldom afford to stabilize more than 1.0-2.0 ppm manganese, whereas the smaller plant may find it possible to treat as much as 5.0 ppm.

Manganese Removal

Manganese is removed from water by the manganese zeolite process or by oxidation. The zeolite process is direct, simple, and subject to a minimum of chemical deviations. There are some differences in the equipment used, which reflects the engineering ideas of different manufacturers. The oxidation processes are varied in character and usually consist of combinations of oxidation, settling, filtration, and catalysis.

Zeolite Process

The manganese zeolite process differs from the sodium ion-exchange process in two important respects: (1) it is strictly a manganese- or iron-removal process (not a water-softening process) and (2) the medium is re-

generated with a solution of potassium permanganate instead of with a solution of common salt. Manganese zeolite is made from refined and processed sodium greensand zeolite by alternate treatments with solutions of a manganese salt and potassium permanganate. It is a black, granular material, serving both as an oxidizing contact medium and as a filter medium.

The capacity of manganese zeolite for manganese or iron is 0.09 lb/cu ft, and the amount of potassium permanganate required to regenerate it is 0.18 lb/cu ft. It is employed in pressure-type filters. The usual rate of flow is 3 gpm/sq ft, but if the manganese or iron content is 0.5 ppm or less, filtration rates as high as 5 gpm/sq ft may be used. When the pressure loss through the filter reaches approximately 6-8 psi, the filter should be cut out of service, backwashed at 8 gpm/sq ft, filtered to waste for a few minutes, and then returned to service. When the rated capacity of a manganese zeolite unit has been reached, it is again backwashed, regenerated with the specific amount of potassium permanganate, rinsed, and returned to service.

For small industrial and household uses, manganese zeolite filters remove manganese or iron from waters containing as much as 10 ppm of these metals. For large municipal or industrial uses, the manganese zeolite process is usually limited to removing manganese or iron from waters containing 1.0 ppm or less of these metals. If used without air, the cost of removing manganese or iron is approximately 0.4 per cent per 1,000 gal per 1.0 ppm of manganese or iron removed.

When a sodium cation exchanger is used in water-softening plants and manganese- or iron-removal plants

treating waters containing 1.0 ppm or less of these metals, the use of manganese zeolite filters has been found to constitute a very simple and effective method of removing the manganese or iron from the bypassed water that is used to bring the residual hardness to the specified concentration. The manganese zeolite process is used on industrial process waters which do not require softening but which do require the removal of small (1.0 ppm or less) but exceedingly troublesome amounts of manganese or iron. Another application is in the treatment of certain waters that are very low in total hardness and pH and contain small amounts of manganese, iron, and hydrogen sulfide. Passing such waters progressively through neutralizing granular calcite filters and manganese zeolite filters raises the pH to 7.2-7.3 and removes the manganese, iron, and hydrogen sulfide. Manganese zeolite filters are very widely employed for household use in conjunction with sodium cation exchanger water softeners for treating and softening hard sulfur waters containing as much as 6.0 ppm hydrogen sulfide.

Oxidation Processes

Oxidation of manganese is accomplished by air, chlorine, chlorine dioxide, chlorine plus copper (catalysis), potassium permanganate, lime at pH values just below the softening range, and lime-soda softening.

Air. Aeration for the removal of manganese is seldom a complete method by itself. In many instances, it is the first step in the process to be followed by the addition of an oxidizing chemical. In some instances, the oxidizing chemical may be added ahead of aeration. The oxidation of man-

ganese by air alone is usually a slow process at the pH values usually encountered in practice. At elevated pH values, however, the oxidation is many times more rapid than at pH values less than 8.0; but even at its best, air oxidation is usually slower than chemical oxidation.

Aeration as a preliminary phase of manganese oxidation is very valuable, because it offers an economical means of releasing carbon dioxide and hydrogen sulfide, which raises the pH of the water and introduces oxygen. This relieves the load on subsequent treatment.

There is no preferred method of aeration. The method to be adopted depends entirely on local circumstances and financial considerations. In one or two places, mild preaeration is obtained by natural aeration caused by the turbulence obtained as the water flows in shallow streams from one reservoir to another. Occasionally, chlorine is added directly to the stream between reservoirs. This is usually done to control algal growths; manganese oxidation is an added benefit. It is more usual, however, to aerate by mechanical means, as in towers or by air forced through diffusers.

Aeration is more effective in hard-water regions than in soft-water regions. This is probably true because soft waters seldom contain much carbon dioxide, but may contain considerable amounts of organic matter that sometimes have a restraining effect on manganese oxidation.

Chlorine. Chlorine oxidizes manganese manganese to the manganic form over a wide range of pH values. At pH values of 8.0 or more and at alkalinites of 50 ppm or more, the oxidation is relatively rapid. At pH

8.0, the time requirements may be approximately 2-3 hr. As the pH increases, the time requirements diminish to the pH values in the softening zone, where the oxidation appears to be complete within minutes. At pH values lower than 8.0, the rate of oxidation appears to be progressively slower as the pH is depressed, until at pH 6.0 the time requirement can be 12 hr or longer. There are little or no experimental data showing whether this slow action at the lower pH values is specifically one of slow oxidation or slow agglomeration of the manganic particles to a size heavy enough to settle or large enough to be removed by filter media.

It is generally recognized, when reliance is placed on chlorine to oxidize manganese, that a minimum of 0.5 ppm free available chlorine residual must be maintained throughout the treatment area. Combined chlorine residuals, because of their low oxidizing potential, do not oxidize manganese. If it is desirable to avoid oxidation of manganese, combined chlorine treatment should be practiced. Although manganese will be oxidized by free available residual chlorine, the resulting product is seldom heavy enough to drop to the bottom of settling basins, even where coagulation is practiced, unless the pH is 9.0 or greater.

In spite of the fact that much of the manganese oxidized by chlorine passes onto the filters, it usually arrives at the filter in a form that will be removed as the water passes through. Practice shows that unless the filter media grains are covered with black manganese dioxide, the filters will pass manganese. It is presumed that the manganese dioxide coating acts catalytically on the colloidal man-

ganese, causing it to drop out on top of the filters.

Chlorine dioxide. Chlorine dioxide, generally speaking, oxidizes man-ganous manganese much more rapidly than chlorine does. For this reason, it is often used in conjunction with chlorine in manganese removal. Chlorine, being considerably less expensive than chlorine dioxide, is usually applied at the head of the plant to satisfy the initial chlorine demand and to start the oxidation process.

Because of its high cost, chlorine dioxide is usually used sparingly and only in those places where the amount of water treated is small and the manganese content is less than 1.0 ppm. The efficiency and speed of chlorine dioxide oxidation depend to a large degree on the pH of the water, just as occurred with chlorine. Best results are obtained when the pH is more than 7.0.

As with the addition of all chemicals, chlorine dioxide should be added at a point where mixing will be rapid and complete. Because it is usually added after chlorination, this sometimes presents a problem that may have to be solved by the construction of special facilities or by rerouting the water flow.

Manganese oxidized by chlorine dioxide will accumulate on the filter sand grains just as will manganese oxidized with chlorine, although most of the manganese at this point will be removed when the filters are washed. Disposal of the manganese-bearing wash water may become a problem.

Chlorine plus copper. The presence of copper ions in water containing free available residual chlorine tends to speed the oxidation of manganese.⁸⁻¹⁰ This was noted as early as 1948 in

Louisiana. Guerney and West¹⁰ were faced with the problem of oxidizing manganese from a well water. Because they knew that copper sometimes acts as a catalyst in certain chemical reactions, they added copper sulfate and chlorine to a series of laboratory samples. The experiment was so successful that the same procedure was utilized in plant practice and found to be effective. Experience in plant operation indicates that the addition of 0.2 ppm copper is very effective and produces results superior to those from the use of chlorine alone.

A similar situation prevailed in a small town in Georgia early in 1950. It was found that the addition of 0.5 ppm copper sulfate to chlorine resulted in better manganese removal than that from the use of chlorine alone. In the Georgia plant, pieces of copper metal were suspended in the flocculating chamber. The appearance of crystals on these plates indicates that manganese is present in the water and that copper sulfate should be added.

It is imperative in this method that the proper amount and type of chlorine be present. This means that the residual should be of free available chlorine and that enough should be added to provide 1.25 ppm chlorine for each part of manganese present. This amount should be in excess of the amount required to satisfy the normal chlorine demand of the water.

Lime. Manganous manganese oxidizes to the manganic form readily at pH values greater than 9.5 under the influence of the oxygen dissolved in the water. At pH values less than 9.5, oxidation must be assisted by the addition of a chemical such as chlorine, chlorine dioxide, or potassium permanganate. Figure 1 shows the relative

amounts of manganese removed at various pH levels by lime alone and by lime plus potassium permanganate at Eau Claire, Wis., on an experimental scale. In plant practice at Eau Claire, the pH is maintained at 9.80. Chlorine is used for oxidation purposes. The lime dosage is variable,

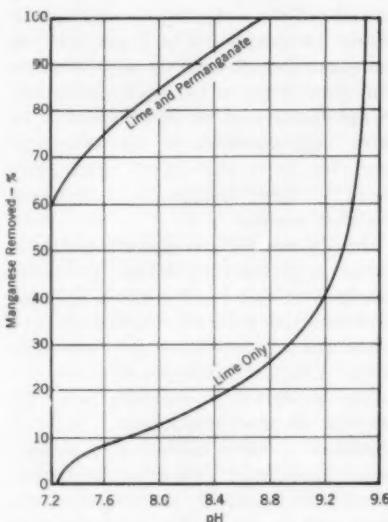


Fig. 1. Manganese Removal With Potassium Permanganate and Lime at Various pH Values

When lime and permanganate were used together, the lime dosage was 2-20 ppm and the permanganate dosage a constant 2 ppm. When lime was used alone, the dosage was 2-70 ppm.

ranging from 2 ppm to 20 ppm. Control of lime addition is obtained by maintaining a hydroxide alkalinity of 10 ppm. This alkalinity allows for some softening and goes beyond the pH required for manganese removal by chlorine, but it seems to be nec-

essary to insure the proper floc characteristics.

Potassium permanganate. Potassium permanganate oxidizes manganese manganese to the manganic form very rapidly. It is used to regenerate manganese exchangers and is used basically in the same manner to oxidize manganese in a slightly alkaline pH range in a conventional water treatment plant. In unpublished reports to the task group, E. Nordell described the use of permanganate in zeolite manganese removal, and L. V. Owens described its use at pH values just less than those required for softening. R. B. Adams described the use of permanganate in the pH range 7.2-8.3.¹¹

When permanganate is used at the lower pH values of 7.2-8.3, problems such as calcium carbonate stabilization, poor coagulation, and color, taste, and odor removal are avoided. In highly mineralized areas, such as in the vicinity of Pittsburgh, the order of application of treatment chemicals appears to be very important. Chlorine is usually added first to oxidize the iron and to satisfy at least a portion of the chlorine demand. The oxidation is then completed by permanganate.

The order of chemical addition when manganese is to be removed should follow that used in the laboratory to establish the chemical dosages. At Wilkinsburg, Pa., chlorine, lime, permanganate, alum, and a coagulant aid are applied in that order. The end product of this oxidation is hydrated manganese dioxide. It is very finely divided and, if present in amounts greater than 1.50 ppm as manganese, can create a real coagulation problem. If the oxidation takes place beyond the floc formation zone, a heavy manga-

nese load may thereby be placed on the filters.

The oxidizing speed of permanganate, according to Adams,¹¹ is quite amazing. Work done by him showed that less than 5 min is required at pH values of 5.0-9.0. The amounts of permanganate required for this oxidation varied from 1.8 ppm at pH 5.0 to 1.0 ppm at pH 9.0.

There are indications that the use of a coagulant aid with alum coagulation results in better manganese removal than the use of alum alone. Experience also shows that approximately 1.0-1.2 ppm permanganate are required for each part per million of soluble manganese in the raw water. This ratio should be checked periodically by laboratory jar tests. One of the main advantages of permanganate treatment is the retention of the manganese in the settling basins. This avoids heavy filter loadings and extends filter runs. At Wilkinsburg, filter runs of 150 hr have been obtained when anthracite filter media * have been used.

Acknowledgment

The author acknowledges the excellent cooperation of all the members of the task group on manganese.† Special data have been accumulated by various individuals on request. Ideas

* Anthrafil, a product of Anthracite Equipment Corp., Wilkes-Barre, Pa.

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and experience have been submitted in volume.

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Microbial Concentration of Iron and Manganese in Water With Low Concentrations of These Elements

Ralph S. Wolfe

A contribution to the Journal by Ralph S. Wolfe, Assoc. Prof., Dept. of Microbiology, Univ. of Illinois, Urbana, Ill. The study was supported by Grant 6430 from USPHS.

VARIOUS microorganisms are known to concentrate iron and manganese in water supplies by depositing hydroxides of these elements in sheaths and stalks or in the slime layer adjacent to the microorganism cell.¹⁻³ Iron bacteria are commonly found in waters that provide a continuous supply of ferrous ions and are most troublesome in water supplies in which the iron content is 1 ppm or greater. A large ensheathed bacterium has been studied that concentrates iron and manganese in its sheaths and that flourishes in a water supply containing, by chemical analysis, no detectable manganese and less than 0.02 ppm iron.

In the filter galleries and on the filters of the Richmond Water Works Corp. at Richmond, Ind., a large hair-like bacterium has been found, which, under low magnification, is shown in Fig. 1, a-c. The hairlike clumps of bacteria are dark gray-brown; the clumps are flocculent when suspended in water. Figure 1d is a phase contrast photomicrograph showing the cells within the sheath. Individual cells measure $2 \times 10-20 \mu$, an unusually large size for bacterial cells. The sheath is clearly visible in the photo-

nicrograph. Older sheaths, which may be devoid of cells, are not as sharply defined. The organisms are not exposed to light in their natural environment.

Laboratory Analyses

Results of a water analysis of samples from Richmond are shown in Table 1. The amount of manganese in the water supplied by either gallery was below the sensitivity of the stand-

TABLE 1
Water Analysis of Samples
From Richmond, Ind.

Constituents	Filter Gallery	
	Gorman	White
	Concentration—ppm*	
Color	—	—
Turbidity	—	—
Alkalinity to phenol-phthalein	—17	—17
Total alkalinity	243	245
Total hardness (as CaCO ₃)	308	322
Manganese	—	—
Iron	0.02	—
Chloride	13.0	12.0

* Dashes indicate that no concentration was detected.

ard analysis, as was also the amount of iron in the water from the White gallery. Water from the Gorman gallery, however, contained 0.02 ppm iron. Both these galleries feed into a common filter, so that the final concentration of iron in the water supplied to the filter, where some of the filamentous organisms grow, was considerably reduced.

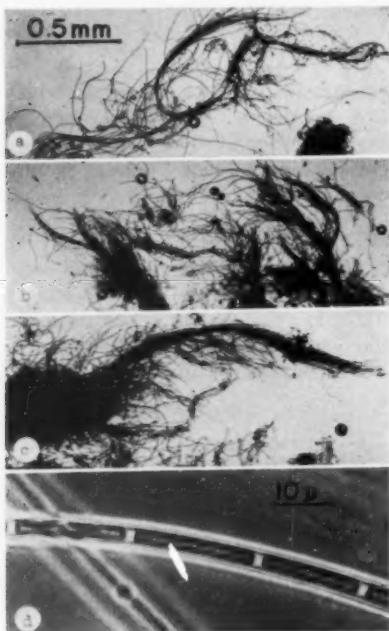


Fig. 1. Photomicrographs of *Clonothrix putealis*

Parts a, b, and c are low-magnification photomicrographs showing the hairlike appearance of the ensheathed filaments (trichomes) of cells. Trichomes are dark brown in color as a result of the deposition of iron and manganese. Part d is a phase contrast photomicrograph of living cells within the sheath.

TABLE 2
Analysis of 40 mg of Dried Bacteria

Constituents*	Percentage of Total Dry Weight
SiO ₂	8.80
MnO ₂	12.00
Fe ₂ O ₃	9.80
PO ₄ as P ₂ O ₅	0.08
Not determined (including organic compounds)	69.32

* The ratio of iron to manganese was 0.9.

In the chemical laboratory of the State Water Survey Division, Urbana, Ill., 40 mg of these dried filamentous bacteria was analyzed. The results of this analysis are shown in Table 2. Iron and manganese account for 28 per cent of the total dry weight, the ratio of iron to manganese being 0.9.

The existence of these bacteria in water with minute amounts of iron and manganese constitutes a unique situation, for it could not be predicted from the results of the water analysis that iron bacteria would be a nuisance under these conditions. Such bacteria may well be more sensitive indicators of iron or manganese than a chemical analysis performed on a limited volume of water, because the organisms are sessile and may concentrate iron and manganese from a large volume of water that flows over them.

Although the organism described here was readily observed by microscopy, attempts to cultivate it in crude or pure culture were unsuccessful. It is tentatively identified as *Clonothrix putealis* (*Clonothrix fusca*),^{4, 5} although the cells, as well as the trichomes in this instance, are much longer than those previously described. The association of *Crenothrix polyspora* with this organism has been previously reported in the JOURNAL.⁶

Acknowledgments

The author wishes to thank A. E. Griffin, of Wallace & Tiernan Inc., Belleville, N.J.; M. E. Flentje, of American Water Works Service Co., Philadelphia; W. H. Shoemaker, of Richmond Water Works Corp., Richmond, Ind.; and T. E. Larson, of the State Water Survey Division, Urbana, Ill., for their aid and interest in these studies.

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Determination of Impurities in Liquid Chlorine

Thomas De Vries and C. P. Savariar

A paper presented on May 18, 1960, at the Annual Conference, Bal Harbour, Fla., by Thomas De Vries, Prof. of Analytical Chemistry, and C. P. Savariar, Postdoctoral Fellow, both of the Dept. of Chemistry, Purdue Univ., Lafayette, Ind.

THE USPHS is sponsoring a research program to investigate methods now used for liquid chlorine analysis and to develop new or improved methods where feasible. At the 1959 AWWA Conference in San Francisco, several analytic methods were discussed, and it became evident that some methods needed further study. For example, the pyridine method for chloroform determination is not specific; other chlorinated hydrocarbons are also measured by it. The chromic acid method to determine hydrochloric acid is troublesome, and it is planned to study the method more intensively. Also studied in 1959 was a method for assaying chlorine,* whereby residual gas volumes were measured in a gas buret after the chlorine had reacted with mercury. This method seems to be satisfactory. The determination of iron chloride in residues obtained by evaporation of a sample of chlorine is readily done colorimetrically, the color being developed with orthophenanthroline in a buffered solution after the iron has been reduced with hydroxylamine.

* Reported by the Solvay Technical & Engineering Service, Division of Allied Chemical and Dye Corp., New York, N.Y.

This method is very satisfactory for iron. In 1959, an evaluation was made of a method already used by some laboratories for determining nitrogen trichloride. With this method, the trichloride was allowed to react with concentrated hydrochloric acid to form ammonium chloride and chlorine. The ammonia was then determined by the kjeldahl method when present in small amounts, or colorimetrically by the nessler method when present in lesser concentrations. Reproducible results were readily obtained.

Silicon Tetrachloride Determination

In recent months, studies have been made of a method to determine silicon tetrachloride in chlorine. It seems that a satisfactory method has been developed.

Silicon tetrachloride is a liquid at room temperature. It has a boiling point of 56.8°C and a freezing point of -70°C. At the boiling point of chlorine, which is -34.6°C, silicon tetrachloride is a liquid with a vapor pressure of 10 mm, and hence will evaporate along with the chlorine if not more than approximately 1 per cent is present. At room temperature, the liquid has a vapor pressure of 125 mm. It fumes rapidly with the moisture in

the air. When dilute solutions in benzene were prepared, it was necessary to use a dry box in which the air was thoroughly dried with anhydrous calcium sulfate.*

A colorimetric method was developed by Boltz and Mellon¹ for water-soluble silicates. The method consists of treating a silicate solution with 1 ml of 7.5 per cent ammonium molybdate. After this solution is allowed to stand for 5 min, approximately 5 ml of 10 per cent tartaric acid solution is added. The yellow suspension is reduced to the heteropoly blue with 1 ml of the 1-amino-2-naphthol-4-sulfonic acid reagent, and the solution is diluted to 100 ml. The transmittancy of the colored solution is measured after 20 min; the color is stable for at least 12 hr. Transmittancies can be measured at 650 $m\mu$ or 815 $m\mu$. The latter was used because greater sensitivity is obtained at that wavelength. The blue color is proportional to a concentration as large as 0.8 mg silicon in the 100 ml of the colored solution. The absorbancy index is 0.78, when the concentration is expressed in parts per million of silicon in the solution being measured; the index is 0.155, when the concentration is given in parts per million of silicon tetrachloride. For example, if a sample of 60 ml (100 g) of liquid chlorine containing 1 ppm silicon tetrachloride by weight is used for a determination, it would contain 0.10 mg silicon tetrachloride. After the required series of reactions is performed, the colored solution would have an absorbancy of 0.155×1.0 , which corre-

sponds to a 70.0 per cent transmittancy in a 1-cm cell inside a spectrophotometer.

The chlorine from a small cylinder was analyzed with the use of 80-120-g samples. The preliminary results varied from 0.8 ppm to 1.5 ppm silicon tetrachloride, but it is apparent that the method can be improved to increase the precision. When an attempt was made to add to a sample of chlorine a known amount (approximately 1 ppm) of the standard solution of silicon tetrachloride in benzene, it was discovered that some of the silicon was lost because of a reaction between the chlorine, benzene, and silicon tetrachloride. This was proved by a spectrographic analysis of a white organic compound that was left behind after the evaporation of the chlorine sample. A new solvent to prepare the standards is being sought which will not result in this difficulty.

The procedure now used for silicon tetrachloride determination allows the liquid chlorine to heat up to room temperature and thus boil away slowly. The gas is bubbled through molybdcic acid-boric acid mixture in two wash bottles, after which the tartaric acid solution and the reductant are added to produce the heteropoly blue compound. The standard solution of silicon tetrachloride in benzene contained a concentration of 25 ppm silicon tetrachloride. It was necessary to redistill the benzene and dry it further with calcium hydride. The concentration of the standard did not change over a period of more than a week. At first it had been suggested that carbon tetrachloride would be a suitable solvent, but it was quickly discovered that the silicon tetrachloride would escape from the solvent in a very short time,

* Drierite, made by W. A. Hammond Drierite Co., Xenia, Ohio.

resulting in a loss of about 50 per cent in approximately 1 hr.

Future Investigations

At present, plans are being made to investigate how the methods of gas chromatography may be applied to the analysis of chlorine. It is proposed to work out a simple method of introducing a sample into a column and to determine the most suitable material to use for the solid support and the stationary liquid in the column. Helium or nitrogen will have to be the carrier gas, because chlorine would react with hydrogen if it were used. The material for the solid support

must also be inert to chlorine at a temperature as high as that of the column, which may be as much as 200°C. The liquid on the column must also be carefully selected.

Another project being considered is a test that can differentiate between impurities that pass through gas-handling equipment and those that may settle out in gas lines, valves, and filters.

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Notes and Comment

Valve Installation and Maintenance

F. S. Wicks

Mgr., Water Dept., Borough of Chelmsford, Chelmsford, England.

Although long an overseas member of the Association I have always read the articles in the JOURNAL with keen interest and often to the advantage of my own undertakings. Excellent as these articles invariably are, I have at times felt that another point of view was worthy of consideration but have heretofore not had the temerity to bring myself to write a letter expressing my views.

Nevertheless, I am now writing in reference to Roy W. Holzer's contribution to the February 1960 JOURNAL on "Installation and Maintenance of Gate Valves in St. Paul" to put forward an alternative layout of mains and valves to that depicted in Fig. 1 on p. 270. The accompanying diagram shows a system which I use, which provides for laying the vertical mains independently of the horizontal mains with simple cross-connections at points where they pass over one another.

In practice, the costs of these alternatives are not materially different. If

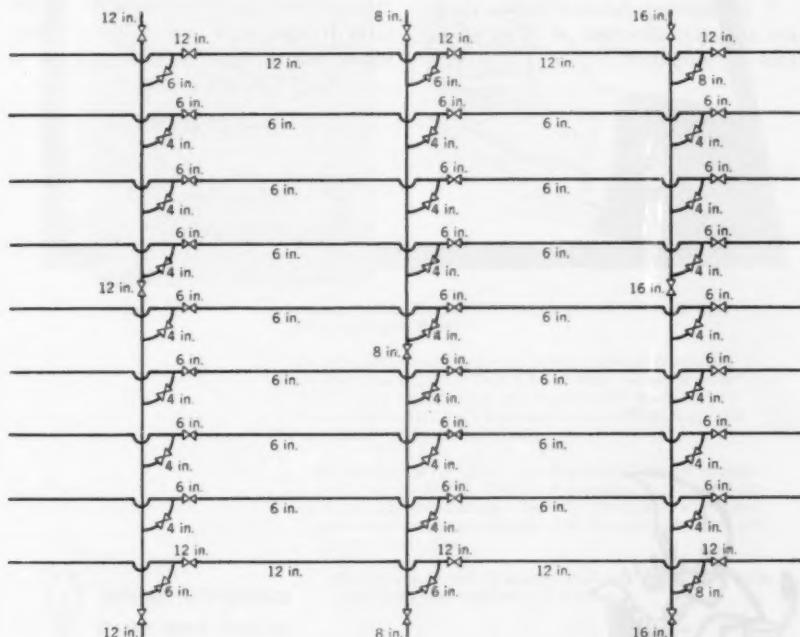


Fig. 1.

a complete reticulation is laid out at one time, the author's system would possibly be the less expensive, but in the more usual progressive development, the edge is in favor of my alternative.

The basic advantage of the alternative system is that the flow of water in any of the vertical mains is not interrupted by a shutdown of any sections of the horizontal mains or vice versa. In my experience, this is a very considerable advantage which brings in its wake a number of real benefits:

1. If trouble develops on the vertical mains, isolation of the fault is effected by closing one valve plus half the number of valves that must be closed in the author's system.
2. In making detailed waste detection surveys, direction of valve operations is simplified.

3. Fewer, and in some cases, smaller valves are necessary.

4. If there is complete catastrophe at a junction, the fault can be isolated, leaving more mains fed from both ends and with less valve operation than in the author's system.

On the other hand, the alternative system entails some deeper excavation where mains pass under each other, and it is necessary to close one more valve in isolating a 6-in. main than in the author's system.

As for the larger mains, I wonder if the author would use a cross section with two 30-in. mains or whether he would lay them as two separate mains with an 18-in. cross-connection. The former can be a monstrous nuisance and produce a ridiculous state of affairs if one must deal with a faulty valve, not to mention the cross.



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The value of a water meter is not what it costs, but what it *earns*. Actually, its "bid price" is only your down payment, and could well be the only *easy* payment.

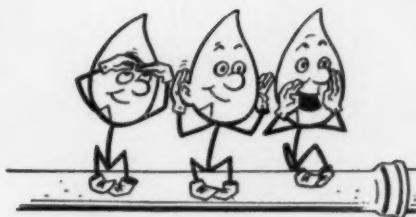
There are two reasons. First, like any fine instrument, a water meter loses accuracy as it wears. If you buy on price alone, you may soon find the meter giving away far more than the few cents you thought you saved.

Secondly, to keep the meter accurate, you may have high repair costs... or premature scrap-and-replace programs.

Water is your city's most vital service. You entrust it to the accuracy of your meters. To be sure of this accuracy, visit your meter shop. Ask which meter gives highest sustained revenue... with lowest repair and depreciation costs.

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3068



Percolation and Runoff

Quality water—water that is not just safe, but soft, palatable, clear, non-staining, and noncorrosive as well—is one of the keystones of AWWA's program of "improved water service." Actually, the concept of selling quality is one that some water works men have trouble embracing—at least with ardor. Not so much "Who needs it?" as "Who wants it enough to pay for it?" has been their main question. People, they say, expect to get their water for almost nothing, as they always have, and will fight any move to make it more expensive. Before we solicit dollars for frills, it is our duty to get the pennies we need for necessities. And this is, no doubt, a practical and understandable attitude in an industry that has always spent more effort defending its right to charge anything—even "a nickel a ton"—for its "God-given" product or in begging customers not to use it, than in selling water.

Meanwhile, the "quality" dollar, together with a lot of those "necessity" pennies, goes elsewhere. It goes to the home softener industry, for instance. And though "zero-softened" water is beyond the scope of the public water supply, the first stages of softening can certainly be more economically handled on a municipal scale.

It goes to the bottled water industry, whose boom last year boosted average sales of members of the American Bottled Water Association to 1.3 mil gal per bottler. And though this industry, too, in supplying spring water and distilled water, goes beyond the services that can be offered by a public water supply, better tap water would undoubtedly reduce the number of bottle users. But, saddest of all, it goes to the do-it-yourselfers—the suppliers of gadgets that may or may not be useful to do the job that the water utility can and should be doing for much less.

Who says people won't pay for a quality water when they are apparently willing to spend \$59 and installation effort to put an Everpure Water Purifier at their sinks, to assure themselves of a chlorine-free drinking water, from which "all dirt, grime, and particles in suspension" and even "microscopic amebic cysts" have been removed? Who says people aren't interested in quality water when the electric "Filter-All" appliance can command a price of "\$199.50 and up" on the basis of "supplying softer, crystal-clear water, increasing life of plumbing and hot-water heaters, eliminating iron and rust stains, and removing taste of chlorine

(Continued on page 36 P&R)

(Continued from page 35 P&R)

and unpleasant odors"? Of course, all a customer needs to do with the "Filter-All" is "just plug it in . . . it never needs attention, no salt, no chemicals, no regeneration, no maintenance or upkeep, no operating expense," but you could certainly save him the effort of plugging it in and, having been saved the price of the installation, he wouldn't be likely to insist that you meet the guarantee of "no operating expenses."

There are other do-it-yourselfers, too. Within the past few months we have noted, for instance, the "Sibco Water Purifier," which "instantly removes rust, iron, sulfur, chlorine, odors, etc., from city or well water," with "no regeneration, no refills, no moving parts, no motors, no chemicals"; the "DSI" process which "puts an end to your hard-water scale problems" by "subjecting the hardness salts that are dissolved in the water to a small but carefully controlled electrical force"; and the "Sofiltro" home conditioner which uses phosphates to sequester hardness-forming salts.

Whether or not the various processes and paraphernalia will live up to their claims we are in no position to report, but what does seem obvious is that a good many people want and are willing to pay for a quality water. It ought to be equally obvious that the basic job of providing a quality water can be handled more efficiently and more economically by the public water utility. So sell, man, sell!

A secret of selling, by the way, is recognizing the competition, so, while you're convincing customers that they want you to supply the quality water they want, you might well put in a good word for the water you are now

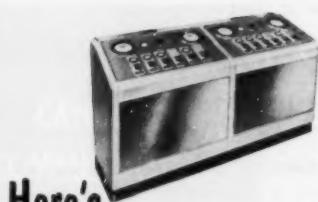
supplying and the way you are supplying it. That you shouldn't take for granted what your customers shouldn't take for granted should be indicated by the fact that 1959 saw an increase of 800,000 in the number of private water systems in the United States and that a single edition of the *New York Herald-Tribune* last July featured three different stories on three different pages extolling their virtues. One of the stories, particularly, reminded us to look to our laurels, in listing these advantages of an individual private water system:

1. Makes possible a wider choice of building sites.
2. Provides an unrestricted water supply whenever it is needed, day or night.
3. Water is fresher. The fact that water is drawn from the well and does not stand in a pipe or reservoirs means constant water freshness which means it is better for drinking.
4. With a private water system, the householder is protected against increases in his water bills.
5. The constant high pressure of a private water system affords protection against fire and protection in the event of an atomic attack.

We rather think that the National Water Well Association, which supplied the list, sort of strained its poetic license or enthusiasm or something. Of course, it was well intentioned.

W. Fred Welsch, who retired on Jul. 1 as senior engineer for the Nassau County (N.Y.) Dept. of Public Works, has formed a consulting engineer firm, W. Fred Welsch and Associates. The new firm, which specializes in water supply, drainage, sewerage, and hydrology, is located in the Post Office Bldg., Albertson, N.Y.

(Continued on page 38 P&R)



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Water Plant
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This complete pneumatic system includes all the essential elements for the operation of water treatment plants. It is used for raw water flow control, flow measurement, chemical proportioning, level control and control of gravity filter operation.

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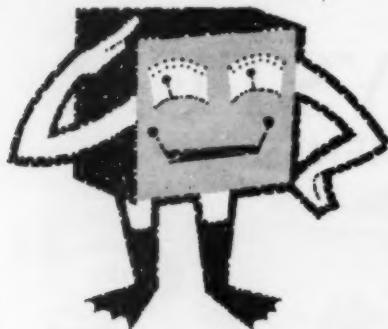
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(Continued from page 36 P&R)

A new character in pollution control has just been introduced by the Ohio River Valley Water Sanitation Commission—an electronic sentinel, the Orsanco Robot Monitor (Orm, to us), designed to perform and report analytical tests on Ohio River water automatically and continuously over a network of 43 observation stations. To be put to work in the fall, Orm (pictured below) consists of three integrated units—an analyzer and transmitter, a telemeter receiver, and a data logger and transcriber. In action he will help guard water supplies for



cities; inform industries on water characteristics; check conditions affecting recreation uses; speed alerts on accidental discharges; discover violations of pollution control laws; reduce the cost of water and waste treatment; and make Ed Cleary, executive director and chief engineer of Orsanco, whose idea he was, practically dispensable.

Roger G. Dittig Jr., assistant professor of civil engineering at Lehigh University, has been named Cast Iron Pipe Research Assn. field representa-

tive for the New England and Middle Atlantic areas, with headquarters in Bethlehem, Pa.

Getting a lift from a camel these days is the water supply story, as a ponderous ruminant named Matilda is stalking the pages of *Time* magazine to dramatize to the reader that his "town may be dying of thirst" without his knowing about it. Pointing out how Matilda may have gotten her nose into our tent and how she may be repulsed is Johns-Manville, whose ad series on water problems is aimed primarily at supporting the industry's public information effort.

Similarly helpful, the Natural Resources Dept. of the Chamber of Commerce of the United States, Washington 6, D.C., has lent a hand in a handbook entitled "Can We Improve Our Water Supply?", outlining the problem and suggesting AWWA among other sources of information on how to solve it. Single copies of this 8-page booklet, directed at arousing the citizen, are available free from the Chamber.

Meanwhile, the National Water Institute, organ of the Water & Sewage Works Manufacturers Association public relations committee, has been continuing its major efforts at keeping the water supply story in focus. Recent NWI projects have included production of the editorial fact sheet, "Water, a Matter of Survival, and Sewage, a Matter of Health," and its distribution to 3,800 daily and weekly newspapers, as well as to AWWA and WPCF members; the production of a television film, "Pennies for Health," and its distribution through TV stations and in communities in which expansion programs are under way; and

(Continued on page 40 P&R)



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West Kildonan is a built-up business and industrial section of Winnipeg, Manitoba. It's also a forward-thinking community, for here TURNALL asbestos-cement PRESSURE PIPE is replacing old-fashioned metal water mains. Low maintenance cost is the reason, for TURNALL PRESSURE PIPE is immune to corrosion, electrolysis and tuberculation, as well as minor shocks and vibrations. Year in and year out TURNALL PRESSURE PIPE does the job without any increase in pumping costs. For your next water or sewage force main installation specify TURNALL asbestos-cement PRESSURE PIPE.

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(Continued from page 38 P&R)

production and distribution of a series of newspaper picture features on water supply and sewage.

Otherwise, on Aug. 3, AWWA Secretary Ray Faust spent a half-hour on WOR Mutual radio in the Galen Drake Show, reviewing the accomplishments and problems of the water supply field. In the Jul. 19 issue of *Look* magazine, an article entitled "Water . . . The Problem That Needn't Be" brought some of the story to millions of readers. Again, in the observance of National Public Works Week, October 2-8, the water supply story got still another telling. And, happily, the more telling it gets, the more telling it becomes!

It will be a long time, of course, before these and related efforts can hope to overcome the accumulated lack of appreciation. A clear indication of the need for increased effort is the fact that water supply system contracts for the first half of 1960 were below the 1959 level. Thus, though free rides via camel or chamber or other nationally oriented vehicles are most helpful, water utilities must realize that they do not make the necessary local stops.

'The Silly Season' proved itself again this year, in water supply as in every other field, specifically not discluding politics. Thus:

On Jul. 25, the Los Angeles *Times*, no doubt under its "Late News" head, ran an Associated Press feature reporting:

Milwaukee officials issued a call for help in locating some of the city's fire hydrants. The missing hydrants were concealed under heaps of plowed snow. Citizens were asked to telephone authori-

ties if they knew where the hydrants were buried.

On Jul. 25, the trial of two London, England, plumbers on larceny charges had to be postponed when water pipes in the courtroom began (sympathetically?) to leak.

On Jul. 26, at Jackson, Miss., an impatient Miss Martha Hierro stuck her finger in the bathtub tap to make the water run faster. An hour later firemen had to break down the door of the bathroom to free her, bare, blushing, and bathbound.

On Jul. 28, United Press International reported from Houston, Tex., that a tavern owner had called police to investigate a suspicious character who drank nothing but water for 4 hr. The man was, of course, bundled off to jail for questioning by a psychiatrist.

On Jul. 31, one of our Editors Anonymous apprised us of the depressing fact that Annex 10, Appendix 2 of the *National Plan for Civil Defense and Defense Mobilization* advises citizens to fill all tubs and containers with water when they hear the attack warning.

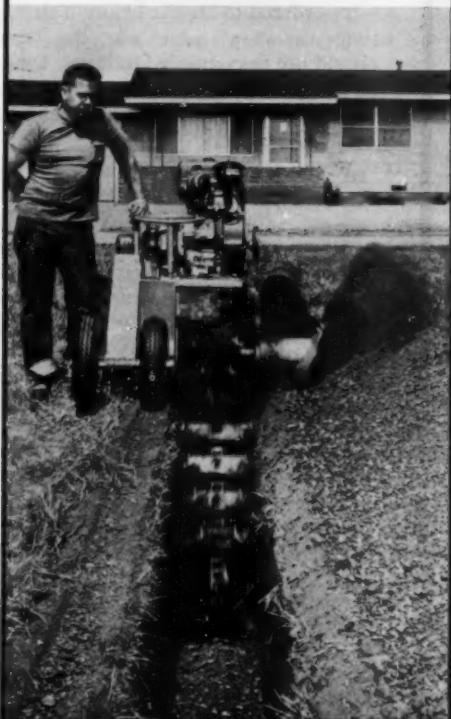
On Aug. 5, Buffalo, N.Y., fire officials reported that an automobile fire, resulting in \$50 damage, had been caused by an unexplained bottle of water which served to focus the sun's rays on a point on the car's upholstery.

On Aug. 8, newspapers the nation over carried the story of Washington Suburban Sanitary Commission Public Information Officer Arthur Brigham's discomfiture on receiving a water bill of \$107 from the commission. It turned out that the bill was based on a reading he had made himself, of his gas meter.

(Continued on page 42 P&R)

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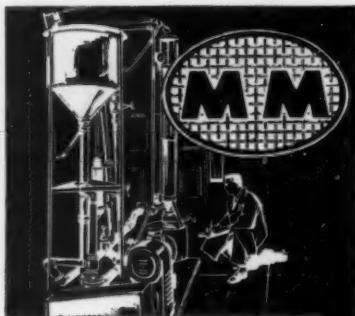
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(Continued from page 40 P&R)

On Aug. 11, from Devine, Tex., came a report of an explosion that caused total loss of a \$10,000 home as a result of ostensibly service-connected efforts by Water Superintendent Kurt Sollock to chase a sick dog out from under the house by using a spray of insecticide and diesel oil.

On Aug. 15, at Williamston, S.C., on petition of a citizen who wanted equitable treatment, Mayor Paul H. Gossett and four town councilmen were ordered to appear before a circuit judge to show cause why the town should not be compelled to install water meters.

On Aug. 17, a-a-a-ah—CHooooo!

Fluoriding high these days is Procter & Gamble Co.—at the Crest, in fact, since their dentifrice of that name has received the endorsement of the American Dental Association as “an effective anti-caries dentifrice that can be of significant value when used in a conscientiously applied program of oral hygiene and regular professional care.” The statement, which appeared in the August issue of the *ADA Journal*, added that Crest may also be of value as a supplement to public water supply fluoridation, thus disappointing many who hoped that this unprecedented action by ADA would break the back of water supply fluoridation, as iodized salt killed interest in water iodization back in the 1930’s. But the report does credit Crest with caries reductions of 23 per cent to 57 per cent in a group with supervised brushing three times daily.

Meanwhile, on the water fluoridation front, Puerto Rico has reported a 65 per cent caries reduction in 7 years and Monmouth County, N.J., a 50

(Continued on page 44 P&R)

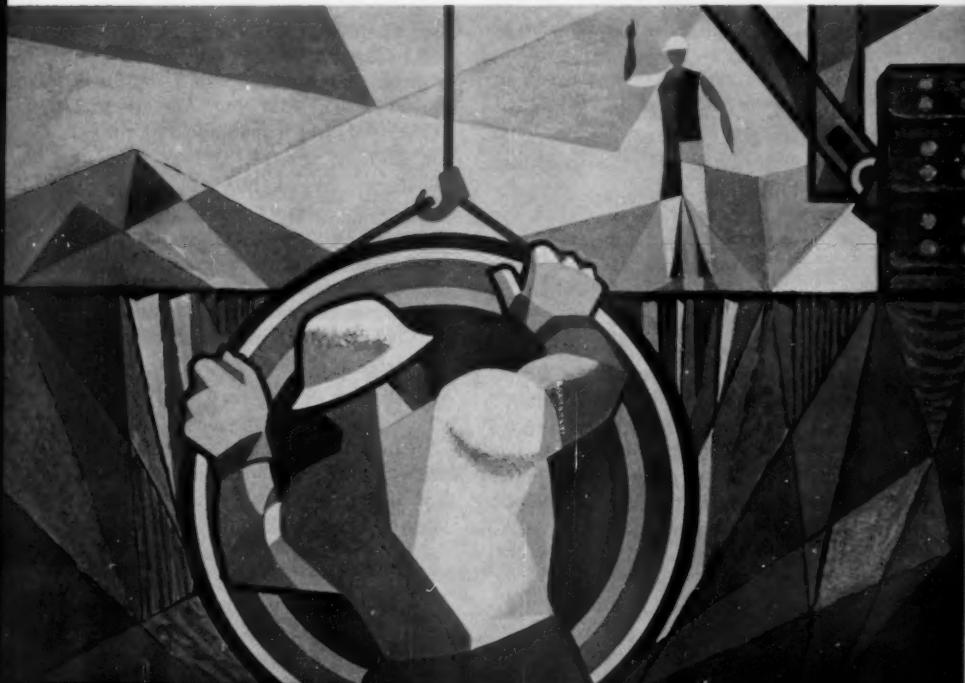


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(Continued from page 42 P&R)

per cent reduction after 5 years. But at Clayton, Mo., in July, a circuit court judge ruled that an ordinance providing for fluoridation of the St. Louis County supply was unconstitutional and at Chapel Hill, N.C., legal action was taken to prevent the University of North Carolina from carrying out its announced plans to fluoridate the Chapel Hill supply.

Internationally, the Federation Dentaire Internationale, meeting in Dublin in June, unanimously voted (28 countries were represented) to recommend fluoridation of public water supplies to all public authorities as the most effective public health measure available for reducing the incidence of dental caries. Nationally, the count as of Jul. 7 totaled 1,922 communities with a population of 37,057,385 fluoridating, served by 1,082 water supply systems. And unsurprisingly, the D.A.R. passed a resolution against fluoridation, as well as the United Nations, foreign aid, the New Deal, and the income tax.

John C. Luthin has joined the firm of Brown and Caldwell, consulting engineers, as vice-president, with an office at San Marino, Calif. He was formerly vice-president of Suburban Water Systems, of La Puente, Calif.

Engineering graduates in 1960 continued to find a favorable employment situation, according to a survey made by Engineering Manpower Commission. In May, 62 per cent had obtained jobs prior to graduation and 11 per cent had offers they were considering. These percentages do not include those entering military service or planning graduate study.

'A horse' these days is no more than a unit for measuring the power of an engine, but recently from Akron, Dallas, and Council Bluffs have come indications that the real thing still exists.

From Akron has come word of a new public parking lot reserved for horses and buggies—an area at Akron's East Branch Reservoir, set aside for the use of Amish fishermen. The reservoir was opened to public fishing in July by agreement with the State Division of Wildlife, which helped provide not only the hitching posts, but two areas for horseless buggies as well.

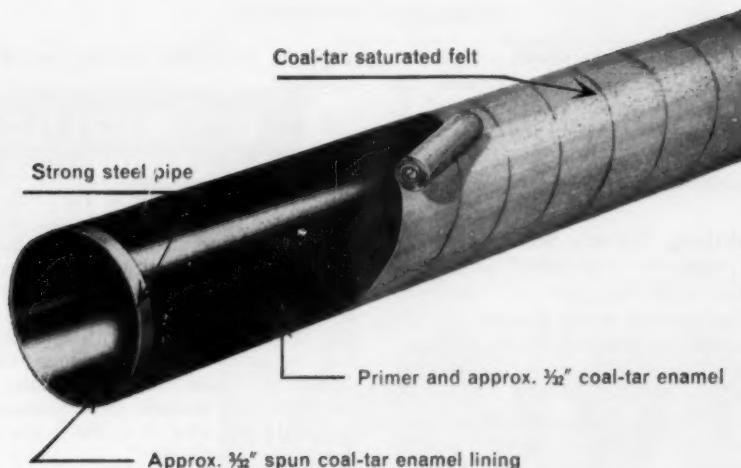
From Dallas, meanwhile, the equine episode was well nigh tragic, when a farm horse named Buck fell in a well and remained there with his nose barely above water for 10 hr despite the efforts of a tow truck crew and a fire rescue unit, until a water supply truck showed up and got him out by pouring in more water and floating him to the surface.

At Council Bluffs, a different kind of buck was involved, the story being that of "The Willing Water \$200 Walking Horse Championship Stake" for stallions, mares, and geldings of all ages. Word has not yet come through on who won, though we were partial to Midnight Pleasure, but Griffin Pipe Division, which sponsored the race, has indicated that Willing Water came through with flying colors.

What we're talking about, of course, is a 1-hp internal combustion, locomotive, vegetarian engine.

Albert L. Sylvester has been elected president of Southern Gas & Water Co., successor by change of name to West Virginia Water Service Co.

(Continued on page 46 P&R)



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(Continued from page 44 P&R)

The company's two wholly owned subsidiaries are Southern Propane Co. and West Virginia Water Co. C. C. MacDonald, president of West Virginia Water Co., was elected vice-president of the parent company.

19

Willing Water's Snollygosters is the name of a proposed volume of water supply anecdotes and jokes now being collected by H. Kenneth Anderson, chief engineer of the Portland, Ore., department of public utilities, and Ken can use your help. He would like to include in the collection everyone's favorites, and, thereby, put together a volume that will be useful to everyone. We might point out that it's wet humor he wants and remind you that, to be used, it must be able to pass postal regulations. As an ex-

ample of what he's looking for, Ken submits:

A drunk staggered into a bar. He bet the bartender that he could tell the ingredients of any drink ever mixed. The bartender thereupon mixed the dregs of several drinks—a martini, scotch, bourbon, and several liqueurs—in a glass. He handed it to the drunk. The drunk carefully sipped the drink and perfectly identified every single ingredient. He offered to do likewise with any other mixture. This time the bartender filled a glass with water. The drunk tested it, meditated for a moment, then announced: "I don't know what it is, but I can tell you this—it won't sell!"

We, who have tasted vodka, could comment, but we'll point out only that Ken's address is 100 City Hall, Portland.

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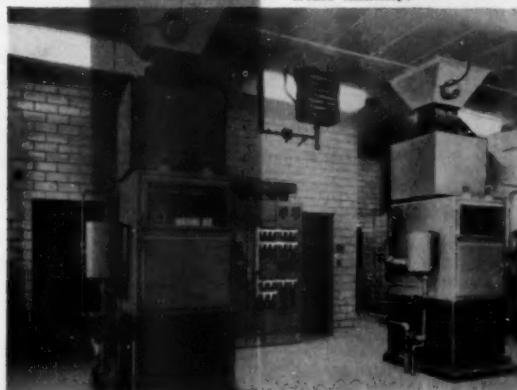
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Please send a complete summary of your education and experience including also your college transcript and a photostatic copy of your military service discharge for Veterans preference points to Henry W. Korner, Executive Secretary, City of Miami Civil Service Board, 3318 Pan American Dr., Miami 33, Fla. The closing date for receiving completed applications is Nov. 16, 1960.

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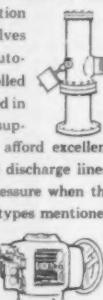


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Correspondence

Quality Is What You Call It!

To the Editor:

I have read with interest Secretary Faust's paper on "Challenges in the Water Industry" (July 1960 *Willing Water*) and its discussion of "quality water." We pride ourselves here in the East Bay District as serving high-quality water. We often wonder why consumers of other water supplies are satisfied with water having obvious taste and odor or turbidity of even a few parts per million. Perhaps they only tolerate the conditions

and assume that water is such a necessity that it must be taken at even low potability.

In our area, nothing irritates me more than the bottled-water company advertisements which refer to our water as "crude," "good for lawns, but not for drinking by our children." Perhaps their ads are true for some supplies, but I am sure we are more concerned with quality.

Along these lines, I believe we should have a new term to describe the water that flows from our treatment plants.

(Continued on page 52 P&R)

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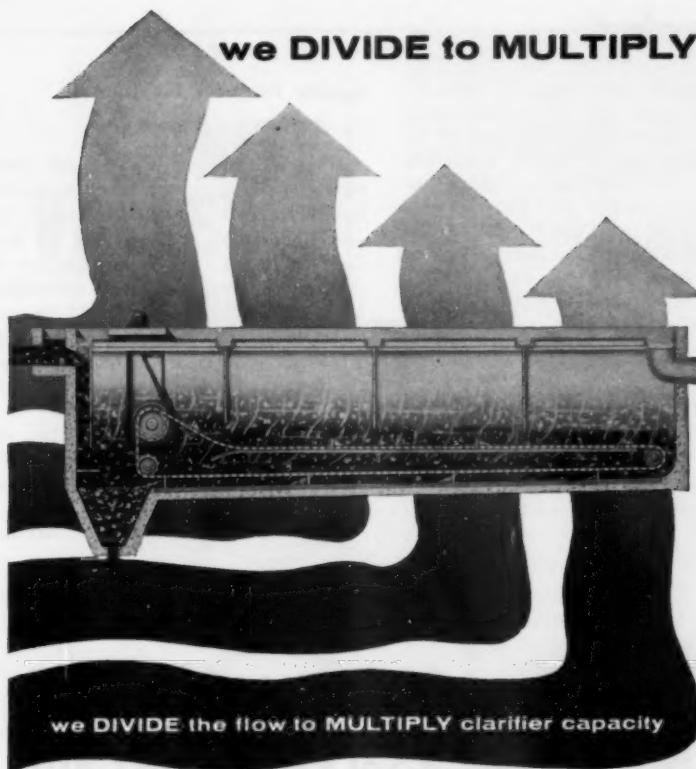
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Correspondence

(Continued from page 50 P&R)

The common terms now is "effluent," which is also used to denote sewage treatment plant flow. One step in emphasizing the need to upgrade water quality would be to give our product a quality name. I suggest that you ask water purveyors all over the country if they can think of a better name. The least that will be gained by discussing the subject is an awareness of quality of water "produced" at treatment plants.

D. G. LARKIN

Mgr., Water Prod. & Distr. Div., East Bay MUD, Oakland, Calif.

Aug. 1, 1960

*And what's wrong with "purified" water, as contrasted to the "putrefied" stuff our sewage works friends put out?—
Ed.*

Double Duty for the Journal**To the Editor:**

Here is a suggestion for those members who do not make a practice of keeping their copies of the JOURNAL. Instead of discarding them, why not send them on to the sanitary engineering department of some college or university? Most such departments should be glad to have an extra copy for their students. If you mark the envelope "Second Class," the postage rate is only a penny an ounce, and 13 cents should be sufficient.

By having these copies available, students may learn the value of AWWA early and become members that much sooner.

ARTHUR F. MELLEN

Hillsdale, N.J.

Aug. 8, 1960



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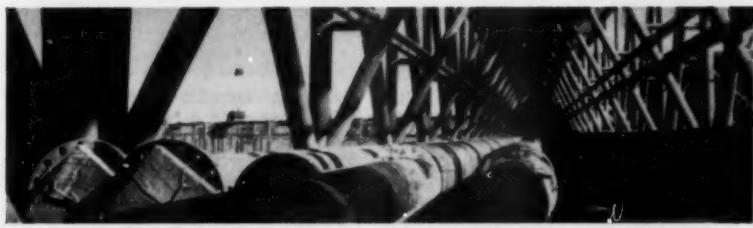
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HYDRAULICS

Design Methods for Flow in Rough Conduits. H. M. MORRIS. *Proc. ASCE*, 85: HY7:43 ('59). Design curves and equations have been developed for determining friction factors for turbulent flow in closed pipes and tranquil flow in open channels.—*WPA*

Roll Waves and Slug Flows in Inclined Open Channels. P. G. MAYER. *Proc. ASCE*, 85: HY7:99 ('59). In an attempt to extend present knowledge of unsteady flow in open channels, a study was made of roll waves and slug flows in an inclined open channel. These were found to be two distinctly different wave patterns. A theory of this type of flow is presented.—*WPA*

Resistance Experiments in a Triangular Channel. R. POWELL & C. POSEY. *Proc. ASCE*, 85: HY5:31 ('59). The results are given in tables and graphs of some expts. on the resistance to flow in open channels, using an adjustable-slope triangular flume which could be smooth or roughened with small rectangular battens at various spacings. It was found that the resistance was greater when the flow was critical or shooting than when it was tranquil. There was a smaller loss for tranquil flow in the smooth channel than for a corresponding smooth pipe.—*WPA*

The Mechanism of Liquid Flow in Packed Columns. M. SHERIDAN & M. DONALD. *Ind. Chemist (London)*, 35:439 ('59). An exptl. investigation is reported and the theory is discussed of the mechanism of flow within packed beds, particularly solid random-packed columns, with special reference to the accumulation of liquid on the walls and the effect on the magnitude of wall flow of changes in the ratio, diameter of column to diameter of units of packing material.

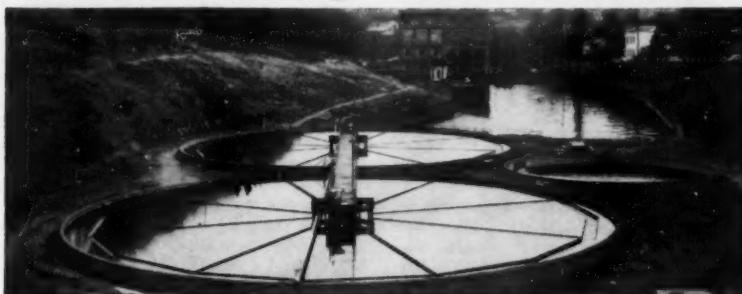
If the latter ratio is large (greater than 30) the effect of the column walls on liquid distribution is negligible, but for columns with a small diameter (so that this ratio is less than 12) serious maldistribution of liquid may occur. The effect of the walls can be obviated either by wall projections to prevent contact between the walls and the packing units, or by using a wall with horizontal corrugations which are small in relation to the diameter of the packing units.—*WPA*

Theoretical Derivation of Tangential Velocity Profiles in a Flat Vortex Chamber—Influence of Turbulence and Wall Friction. K. RIETEMA & H. KRAJENBRINK. *Appl. Sci. Research (Neth.)*, 8:177 ('59). As part of a study on the hydrodynamics of a cyclone separator, a theoretical investigation of the flow pattern in a flat box cyclone (vortex chamber) has been carried out. Expressions have been derived for the tangential-velocity profile as influenced by internal friction (eddy viscosity) and wall friction. Because of the close relation between eddy viscosity and eddy diffusion, measurements of velocity profiles in flat box cyclones will also provide information on the eddy motion of particles in a cyclone, a motion which reduces its separation efficiency.—*WPA*

A Unified Theory of Turbulent Flow—I. Formulation of the Theory. W. SQUIRE. *Appl. Sci. Research (Neth.)*, 8:158 ('59). A critical analysis is made of the assumptions underlying Reynolds' equations for turbulent flow. It is shown that there are regions in a flow field where these assumptions break down and it is therefore necessary to separate the flow into a turbulent core and a laminar sublayer. A set of equations for calculating turbulent flows is proposed. The theory enables the idea of a large eddy viscosity to be applied even where the velocity gradient is large.—*WPA*

(Continued on page 64 P&R)

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(Continued from page 62 P&R)

Discharge Measurement in Circular Pipes With Current Meters. M. BLAHO. *Periodical Polytech., Eng. Ser.* (Budapest), 2:77 ('58). Under conditions where simple orifices or venturi tubes cannot be used, the volume of liquid or gas flowing in a pipe can be measured by the velocity-area method in which the velocity of flow is measured at various points in the cross section in the pipe, usually by means of the Prandtl tube, and the discharge is then calcd. The mathematical basis of computing the discharge from the measured velocity distribution is outlined. It is recommended that the velocity should be measured at 10 points along each of 2 diameters. If the flow is turbulent, the results obtained by this method can be corrected by reducing them by 0.5%. The errors involved in this method are also considered, particularly that introduced in the computation of mean velocity, which should not exceed half the difference between the 2 mean values computed along the 2 diameters considered. If the error exceeds a permissible limit, the measurements should be repeated along 1 or 2 other diameters.—WPA

Developments in Differential Producers for Flow Measurement. H. E. DALL. *Instr. Engr.*, 2:144; 153 ('59). The differential-pressure method for the measurement of flow in pipes compares favorably with other methods, and details are given of various types of differential producers developed for special uses, particular attention being paid to intake devices, devices for flow measurements at low Reynold's numbers, and less common special devices. The installation of these devices under difficult conditions, and the assistance given by flow straighteners are discussed. Low-pressure-loss devices using streamline curvature—for example the Dall tube, the Dall orifice, the Dall pitot, and other special venturi and pitot tubes—are considered in detail, with the aid of diagrams.—WPA

Velocity-of-Approach Factors in Unified Weir Equations. F. ENGEL & W. STAINSBY. *Proc. Inst. Civ. Engrs.* (London), 9:145 ('58). In equations for flow in rectangular channels over freely discharging weirs, some authorities have combined the head with the velocity of approach, while others combine

this term with the coefficient of discharge, which can also take into account the geometry of the weir design and fluid properties such as viscosity and surface tension. The authors suggest that the consideration of the velocity-of-approach factor as a separate term, linked with neither the head nor the discharge coefficient, may be useful in interpreting other pertinent factors. One advantage of this is a simplified evaluation of weir flow measurement. Knowing the head, the discharge can be calculated directly instead of in steps of approximation. In addition, the proposed type of basic flow equation, being equally valid for sharp-crested as well as long structures, or standing-wave weirs, permits the discharge coefficient itself to be used in studying the factors which are influenced by weir design and by characteristics of fluid dynamics.—WPA

Hydraulic Problems in the Development of Apparatus for Measuring Speed and Resistance. O. FALK. *Wasserwirtschaft* (Stuttgart), 48:344 ('58). In an illustrated article the author deals with apparatus and methods for measuring rates of flow. Apparatus described includes a trolley arrangement for standardization of measuring instruments, a torsion measuring apparatus, and pitot tube apparatus. Investigations on the use of apparatus are described and the measurement of very small speeds and of countercurrent flows in the neighborhood of ships' propellers are discussed.—WPA

Boundary Between Suspended Matter and Bottom Transport. J. BURZ. *Wasserwirtschaft* (Stuttgart), 48:387 ('58). The author discusses theories of and factors affecting the movement and sedimentation of suspended particles, with special reference to calculations of size and the effects of turbulence on distribution. Model expts. are described which show that regular distribution occurred only with particles of diameter up to 0.1 mm; larger particles accumulated near the bottom where their movement was different from that of true suspended matter. This, however, applies to the artificial exptl. channel only; in natural channels turbulence depends on rate of flow and on the shape and roughness of the channel so that the limiting value must be determined for each case. Measurements in a number of rivers are given.—WPA

(Continued on page 66 P&R)

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(Continued from page 64 P&R)

Storm Water Overflows—Operation and Design of a Stilling Pond. D. SHARPE & T. KIRKBRIDE. *Proc. Inst. Civ. Engrs.* (London), 13:445 ('59). In designing storm water overflows, the use of stilling ponds has many advantages as it not only permits comparatively accurate regulation of the flow but also results in less polluting matter being discharged. Model expts. were carried out on the operation of stilling pond overflows with a view to determining the conditions limiting chamber design and to deriving suitable design standards. The flow patterns within a stilling pond were first investigated and the limiting conditions deduced therefrom are presented in a simple form for design application. The applicability of the results to the performance of full-scale overflows is being studied.—WPA

Testing and Calibration of Storm Overflow Control Pipes. K. HUTTON. *Eng. & Contract Record* (Toronto), 70:23:13 ('59). The stilling pond overflow pipe, which pro-

vides the most efficient means for the separation of 6 times the dry-weather flow from storm water flows, and for removing suspended solids from storm water, is described, and the one in use at Mixenden is presented diagrammatically. Tests carried out at Halifax on this type of overflow and its calibration are given in detail, and show the variation between discharges allowed for in design and those met with in practice. Equations are derived for the determination of several factors including the hydraulic gradient, velocity head, and friction loss. From the studies so far carried out, it was concluded that the stilling pond is the best type of storm overflow at present in general use.—WPA

Calibration of a Gaging Weir on the River Wandle. P. ACKERS & B. SAY. *J. Inst. Munic. Engrs. (Gr.BR.)*, 86:48 ('59). The results are given in tables and graphs of expts. on the use of a sectional model for calibrating a gaging weir at Middle Mills

(Continued on page 68 P&R)

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(Continued from page 66 P&R)

on the River Wandle before it flows into the tidal Thames. The data obtained were modified for side spillway effects.—WPA

Calibration of a Submerged Broad-Crested Weir. R. A. SMITH. *Proc. ASCE*, 85:HY3:1 ('59). The author discusses the calibration of a completely submerged weir in which tailwater phenomena control the discharge. It is shown that discharge is a function of the degree of submergence, whereas with free overfall the discharge is a function of the head on the weir. After calibration, the computed discharge when compared with the observed discharge showed a probable deviation of about 2%.—WPA

Tabular Solution of Open-Channel Flow Equations. H. A. BABCOCK. *Proc. ASCE*, 85:HY3:17 ('59). A table is given for use in solving cubic equations which arise in problems of flow in open rectangular channels. Some examples of its use are included.—WPA

Relationships Between Pipe Resistance Formulas. W. L. MOORE. *Proc. ASCE*, 85:HY3:25 ('59). The relation between modern concepts of pipe resistance and the older empirical formulas is discussed, and a simple procedure is developed to derive an exponential formula applicable to a known range of flow conditions. Limitations of the equivalent-pipe concept are discussed. Data on resistance measurements in water mains in service indicate that the head loss varies with the discharge to a power nearly equal to 2.0, rather than 1.85 as is commonly assumed.—WPA

LABORATORY METHODS

The Prop Technique for Colony Counts in Microbiology. J. DAVIS & J. BELL. *Lab. Practice* (London), 8:58 ('59). The authors discuss the use and the advantages and disadvantages of various types of dropping pipet for measuring the volume of suspension added to a culture medium for estimating colony counts. The drop technique has many advantages over other methods of estimating colony counts, when a large number of tests is involved. Details are included of the use and calibration of the platinum tube type of pipet, consisting

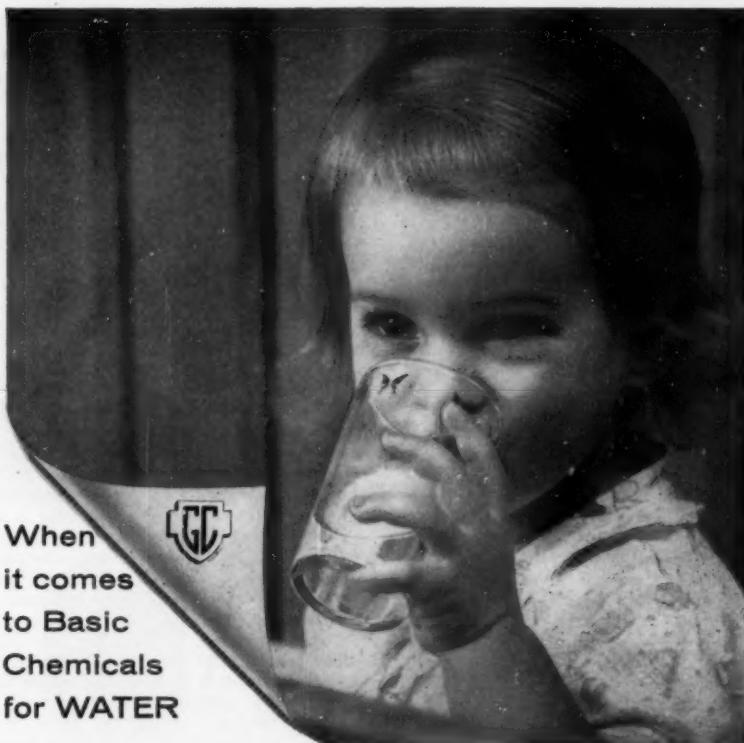
of a short length of platinum tubing sealed into a bulb pipet. No difficulties were encountered in sterilizing the pipet and the reproducibility of the drop size was good.—WPA

A New Spectrophotometric Method for the Determination of Small Amounts of Chloride in Water. I. IWASAKI ET AL. *Bul. Chem. Soc. (Japan)*, 29:860 ('56). Chlorides react with mercuric thiocyanate forming mercuric chloride and thiocyanate which in nitric acid soln. forms with iron alum a red-orange compd. with an absorption max. of 460 m μ . The intensity of color is increased by dioxane. As the coloration is dependent on temp. the determination and the preparation of the std. curve must be carried out under the same conditions. The method is applicable to concns. between 0.05 and 80 ppm. Most interfering substances are not naturally present in water. Details of the method are given.—WPA

A Colorimetric Method for Microdetermination of Chloropicrin in Water. R. FOURNIER & M. PERSON. *Chim. Anal.* (Paris), 160:150 ('58). The authors describe a method for the determination of chloropicrin in water which depends on colorimetric measurement of the strongly colored complexes formed by chloropicrin with potassium cyanide and phloroglucinol. The reaction is specific and is sensitive to 4 μ g of chloropicrin per ml. The theory of the reaction is discussed.—WPA

Determination of Fulvic Acids in Water. A. L. WILSON. *J. Appl. Chem. (London)*, 9:501 ('59). In order to compare the efficiency of different types of demineralization plant and of different methods for the preliminary treatment of the water, a method was developed for the determination, in different waters, of the fulvic acids which cause organic fouling of the strongly basic anion-exchange resins. The method, described in an appendix, is based on a method involving measurement of the ultraviolet absorption spectrum of the sample and comparison with a calibration curve, and was found to be sufficiently sensitive, precise, and accurate for use in the examination of soft moorland waters. Preliminary treatment is necessary to prevent the difficulties

(Continued on page 70 P&R)



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caused by colloidal hydroxides. The fulvic acid composition of moorland waters from many different regions of England and Wales was similar and the concns. were in the range of 1.7-30 ppm. The method may also be applied to hard well waters, but corrections may be necessary for the effects of silica and nitrate; these waters contain considerably lower concns. of fulvic acids than the moorland waters, and therefore cause less organic fouling of the ion-exchange resins. The presence of fulvic acids was confirmed in the water supplies of power stations where organic fouling of the resins had occurred.—WPA

Determination of Organic Matter in Water by Oxidation With Potassium Permanganate. A. L. WILSON. *J. Appl. Chem. (London)*, 9:510 ('59). The permanganate method as described by the American Public Health Association for the determination of organic matter was modified for use in the examination of moorland waters and found to be simple, rapid, and of adequate precision. Moorland waters from various parts of England and Wales were analyzed by this method, and the results were compared with those obtained by the ultraviolet method [see preceding abstract]. It was concluded that the moorland waters contained other oxidizable organic compds. in addition to fulvic acids; the fulvic acids account for 68-94% of the oxygen demand of the samples. The relative composition of any particular water remains fairly constant. On the basis of these results, the use of the method to determine the approx. concn. of fulvic acids in moorland waters is discussed.—WPA

Determination of Alkyl Benzene Sulfonates in River Waters and Sewage. H. WEBSTER & J. HALLIDAY. *Analyst (Gr. Br.)*, 84:552 ('59). An improved colorimetric method has been developed for the accurate determination of alkyl benzene sulfonate in water. The method is less subject to error from naturally occurring substances than is the Longwell and Maniee method. Interference from hydrolyzable materials is prevented by acid hydrolysis, and the detergent is then isolated from many interfering substances by amine extractions. The results obtained agree well with the referee infrared method, but the proposed method is

(Continued on page 74 P&R)

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(Continued from page 70 P&R)

more rapid and convenient and does not require specialized equipment. The method can also be used satisfactorily to analyze sewage works effluents and settled sewage. Detailed procedure is given.—WPA

The Determination of Anionic Detergents in River Water. J. G. SLACK. *Analyst* (Gr.Br.), 84:193 ('59). A modification of the Longwell and Maniece method for determining anionic detergents is described, which involves extraction of the detergent-methylene blue complex with only one 50-ml portion of chloroform, and is therefore less time consuming. The original and the proposed methods were compared by tests on solns. of Manoxol OT in distilled water, and the results obtained by both methods in the examination of river water and sewage effluent are also tabulated.—WPA

Chelatometric Determination of Sulfates in Water, With Calcein as Indicator. M. EFFENBERGER. *Chem. Listy* (Czech.), 52: 1501 ('58). An indirect complexometric method for determining sulfates in water, based on the precipitation of sulfate ions as barium sulfate and titration of the excess barium ions with EDTA using calcein as indicator, is described. The method is suitable for determining sulfate ions over a wide range of concns. The concn. of calcium in a 100-ml sample is first determined with EDTA using potassium hydroxide as buffer and calcein as indicator; when heavy metallic ions are present a suitable quantity of triethanolamine and potassium cyanide is added to prevent interference. A second 100-ml portion of the sample is acidified with 0.1*N* hydrochloric acid. This is then boiled, a suitable volume of 0.005-0.02*M* barium chloride soln. is added, it is boiled again for 2 min, left to stand on a water bath for 20 min and the barium sulfate is filtered off. The ppt. is washed with 20 ml of hot water, the filtrate is cooled, 5 ml of *M* potassium hydroxide is added, with triethanolamine and potassium cyanide if necessary, and the soln. is titrated with EDTA to determine excess barium and calcium.—WPA

Omega Chrome Blue Green BL as Analytical Reagent for Calcium and Magnesium. A. RAHEEM & A. MOUSTAFA. *Anal. Chim. Acta* (Gr.Br.), 21:379 ('59). The behavior of Omega Chrome Blue Green

BL towards various metal ions was studied. It was found that it could be used as an indicator in the direct titration of calcium and magnesium with EDTA, and also in the titration of magnesium in the presence of aluminium. The titration can be done in the cold, but better endpoints are obtained at about 60°C. The endpoint is also improved by the addition of a few ml of acetone or ethanol.—WPA

Water Testing and Treatment Techniques for Field Use. W. M. WARD. *Can. J. Public Health*, 50:159 ('59). In a paper presented at the 9th Annual Institute for Sanitary Inspectors at the Univ. of Manitoba the author described various water-testing and treatment techniques for use in the field including detection of tastes and odors and their control by superchlorination and by activated carbon, the fluorescein test for tracing the movement of surface and ground waters, and a simple kit for testing the hardness of zeolite-softened water.—WPA

A New Simple Water Sampling Apparatus. G. GAD. *Gesundh. Ing.* (Ger.), 79:232 ('58). The author describes a sampling apparatus designed to avoid contact of a water sample with air. The container is cylindrical with a valve at each end. On sinking the apparatus through the water the valves are opened by the water so that there is a constant flow through the apparatus; on raising the cylinder the pressure of water closes the valves.—WPA

Liquid Sampler. *Wtr. Waste Treatment J.* (Gr.Br.), 7:327 ('59). An automatic liquid sampling device developed at the Mogden sewage works of Middlesex County Council is now being manufactured commercially. The operation of the machine is described with the aid of a photograph and a diagram. The machine operates at regular intervals by means of a time switch, pumping a sample of water into a float tank; liquid from the outflow pipe of the tank enters a measuring hopper and when the hopper contains the predetermined vol. of sample it tips, discharging through a funnel into a sample bottle, and also closing the outflow pipe. The pump then stops, the float tank is emptied, the outflow is reopened for the next cycle, and the funnel rotates ready to discharge into a different sample bottle. When

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(Continued from page 74 P&R)

all the bottles on the bottle carrier have been used, the funnel is rotated to a position where no sample can be contaminated.—WPA

A Grab for Quantitative Sampling in Stream Muds. J. FORD & R. HALL. *Hydrobiologia*, 11:198 ('58). An illustrated description is given of a grab for taking accurate samples from a small area of muddy bottom to a known depth. The closing mechanism consists of a pair of steel plates accommodated in the open position on shelves on either side of the aperture, and which are snapped shut by an upward movement of an inner handle.—WPA

A Handy Hydromechanical Sampling Apparatus for Bacteriological Examination of Water. P. KRAUS. *Zeitblatt Bakteriol.* (Ger.), 172:458 ('58). An illustrated description is given of apparatus suitable for taking samples for bacteriologic examination from any desired depth of water. The apparatus is suspended on and operated by a single wire rope and is suitable for any type of sampling flask closed by a plug stopper. —WPA

Apparatus for Taking Water Samples at Any Desired Depth. *Gas- u. Wasserfach.* (Ger.), 100:307 ('59). An illustrated description is given of apparatus by which samples of water can be taken from any desired depth, uncontaminated by water from other depths. The apparatus is suitable for obtaining samples for bacteriologic, biologic, and chem. examination.—WPA

Modification of the Hayward Orange Peel Bucket for Bottom Sampling. D. J. REISH. *Ecology*, 40:502 ('59). Modifications to the Hayward orange-peel bucket to render it suitable for use as a bottom sampler, are described and illustrated with the aid of diagrams. The advantages and disadvantages of the apparatus are discussed; a few of the latter have been eliminated by the modification in design.—WPA

A Simple Counting Chamber for Nannoplankton. J. W. LUND. *Limnol. & Oceanograph.*, 4:57 ('59). A detailed description is given of a simply made, cheap chamber for counting nannoplankton. The chamber is simply a rectangular glass tube. Instruc-

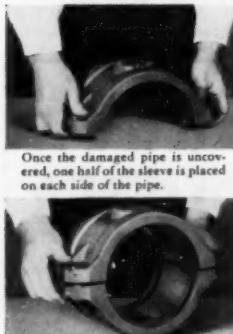
(Continued on page 78 P&R)

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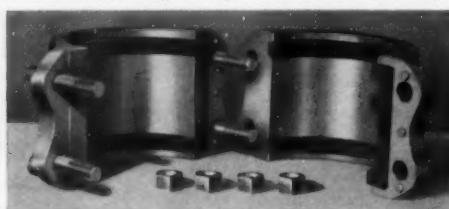
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(Continued from page 76 P&R)

tions for maintenance and use of the chamber, and for testing its accuracy, are given. If certain precautions are taken, the results of counts made with the chamber are distributed according to the Poisson series.—*WPA*

Capacitor Thermometer for Hydrologic Investigations. S. SRIVASTAVA & V. PADMANABHAN. *J. Sci. Ind. Research* (India), 18B:345 ('59). A description is given of the design and operation of a capacitor thermometer used by the Indian Naval Physical Lab. to study temp. variations in shallow waters, particularly in connection with hydrological studies on estuaries where the depth does not often exceed 50 ft.—*WPA*

CHEMICAL ANALYSIS

Water Analysis. L. THATCHER & R. KISER. *Anal. Chem.*, 31:776 ('59). A review of major work published in the field of water analysis during the years '57 and '58 is presented. The subjects covered include instru-

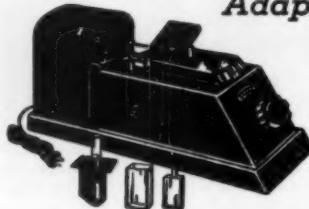
mentation, flame photometry, alkali and alkaline earth metals, complexometric titrations, copper, zinc, iron, aluminium, trace elements, selenium, boron, chlorides, bromides, iodides, fluorides, sulfates, phosphates, silica, nitrogen compds., dissolved gases including oxygen and chlorine, organic compds. syn. dets., BOD and chem. oxygen demand, radioactivity, uranium, radium, thorium, isotopic analysis, quantitative removal of salts from rainwater, potentiometric determination of sulfate, chloride, and nitrate in water, fluorometric and colorimetric methods for the determination of sulfide and cyanide, and ultraviolet spectrophotometric procedures for the determination of sulfate and chloride.—*WPA*

Biochemical Oxygen Demand of Lake Water—I. M. STANGENBERG. *Mem. Ist. Ital. Idrobiol. Dott. Marco De Marchi* (Milan), 11:185 ('59). The BOD of lake water is discussed on the basis of tabulated and graphical data which were obtained during investigations in '57 on Lake Maggiore,

(Continued on page 80 P&R)

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PIPE LINE EQUIPMENT

(Continued from page 78 P&R)

Italy, and 12 Polish lakes, of various types, the observations in Lake Charzykowo being repeated in '58. The 5-day BOD value at 20°C was found to range from 0.4-7.9 mg/l of oxygen according to the type of lake and the depth at which the sample was taken. The BOD of water from unpold. lakes sometimes reached the levels characteristic of pold. waters, showing that large amts. of organic matter accumulated in some dystrophic lakes. The observed values of the BOD differed considerably from the theoretical values, owing to differences in the biocoenotic compn. and the degree of decompn. of the organic matter; in particular there is a pronounced difference between the upper epilimnion and the deeper layers of water. Stratification of BOD occurred in the lakes to an extent depending on the type of lake; and was very pronounced in eutrophic lakes. The results suggested an accumulation of organic matter above and just below the metalimnic water. When the water was filtered by various methods, the observed BOD values were increased; this effect is attributed to mechanical stimulation or separation of single bact. cells from the colonies. The addition of phosphate or nitrate to either raw or filtered water usually increased the BOD value. In an appendix the author considers the classification of Lake Maggiore in the eutrophic system.—WPA

Behavior of Humic Material in Water—III. Study of the Dispersion, Adsorption, and Desorption of Humic Acids and Clays. G. V. BENEDEN. *Bul. Centre Belge Etude et de Document. Eaux* (Liege), 39:35 ('58). Following the studies of the relation between humic material and colloidal matter and iron in waters of the Hautes Fagnes district, Belgium, the waters were examined to investigate the relation between humic material and clays, which cause silting in impounding reservoirs, and can reach the water distribution systems, with part of the humic material which they have adsorbed. Treatment of these waters containing humic material and humic iron is difficult; filters quickly become blocked and ion-exchange units cannot be regenerated. The presence of humic material increases the amt. of clay put into suspension by erosion and causes suspension of clay even when the movement

of the water alone would be too small to do so; it also inhibits the final sedimentation of the clay. The rate of sedimentation of the clay alone increased with the acidity; in the presence of humic material the dispersion of clay was greater owing to the formation of a complex between the clay and the humic material, particularly at pH 4. This effect was greatest in times of flood when the waters were most acid, most rich in humic material, and most affected by erosion. It was found that in aqueous phase excess humic material, as at the source of a watercourse, would peptize the clays; but in highly colored waters, as from open peat bogs, excess clay would adsorb the humic material, and this adsorption was increased by the presence of ochre. Humic material combined with iron was found in white, and particularly in yellow, clay; the iron humate promotes the flocculation of humic acids in acid soln.; in the presence of peat extracts and added ferric salts, a pH value of 5 was sufficient to cause flocculation of humic acid and immediate sedimentation of the colloidal clay. The studies have indicated that by a repeated successive of peptization, adsorption, and desorption, the humic material, clay, and iron, sometimes free and sometimes combined, are moved to the silt and muds of river banks, estuaries, and lake reservoirs. The desorption of various elements from these clay-containing muds buried under water was also studied. A biochemical reaction was found to predominate and lead to various phenomena, including formation of soluble sulfur, displacement of iron in the deposits, transfer of humic material from the sludge to the supernatant water, and appearance of soluble iron in the liquid phase near the sludge. In a lake, for example, although the iron is precipitated and settles after oxidation in the upper more-aerated layers of water, the humic material remains distributed throughout the water and prevents the sedimentation of clay particles entering the lake. These phenomena are considered in relation to the quality of water supplied from an impounding reservoir or lake and to the explanation of the low efficiencies of sedimentation in lakes supplied with water rich in humic material. The data will also be useful in studying the corrosion of metal pipes by this type of water.—WPA

(Continued on page 82 P&R)

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(Continued from page 80 P&R)

The Cycle of Nitrogen, Sulfur, and Phosphorus in Water. E. SCHULZE. *Wasserwirtsch. Wassertech.* (Ger.), 8:38 ('58). The author describes the behavior of the 3 elements nitrogen, sulfur, and phosphorus in water, with special reference to bacterial action, the control of formation of hydrogen sulfide by addition of nitrate, the influence of the elements on the productivity of water, and the dangers of the introduction of excess phosphorus in sewage or drainage from manured fields.—WPA

Relations Between Measurements of Turbidity and Nonsettleable Suspended Material. G. NOISETTE. *Bul. Centre Belge Etude et de Document. Eaux* (Liege), 45:139 ('59). Measurements of the turbidity of water have been used principally to control filtration processes and to detect the appearance of poln. in water supplies, but studies are in progress to extend the field of application by interpreting the results as a measure of the content of nonsettleable suspended matter.

As the first stage of this study, the use of clay suspensions as reference stds. has been investigated. Methods are outlined for purifying the clay and preparing dispersions (containing particles of about 1μ or less) by subjecting suspensions of the purified material to ultrasonic vibrations. The turbidity of the dispersions was measured with a Pulsfrich turbidimeter with light (white or monochromatic at 620 or 520 $\text{m}\mu$) incident at 45 deg. For suspensions contg. 0-50 mg/l of clay, a linear relation was found between the turbidity and the concn. of clay in suspension. For natural waters where the colloidal material consists of a mixture of clay, mud, and organic material, a calibration curve can be obtained similarly, showing the relation between the turbidity and the concn. of un settleable suspended matter, if the suspended material is dispersed by the ultrasonic method; the curve obtained is only applicable to the particular water and the particular type of suspended material investigated.—WPA

(Continued on page 84 P&R)

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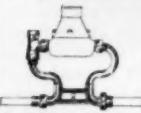
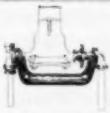
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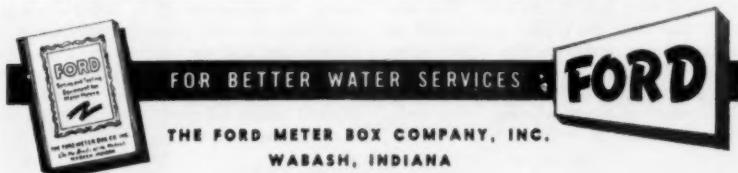
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You get the breaks on new inventions		7. Ford Research Keeps You Out in Front For over 60 years Ford has specialized in developing and producing better equipment for setting and testing water meters. Stay "out in front" with Ford.



(Continued from page 82 P&R)

Changes in Sedimented Material in Retention Basins. G. V. BENEDEN. *Bul. Centre Belge Etude et de Document. Eaux* (Liege), 45:125 ('59). After discussing the formation of sediments, both in flowing and stagnant waters, and also in water pipes and during the coagulation of water with aluminium and iron salts, and the inert or evolutive nature of the sediments, the author gives individual consideration to "nonpold" sediments, consisting only of materials of natural or vegetable origin, and not contaminated by wastes of human or animal origin; to pold. sediments, rich in material of animal origin; and to sediments formed during coagulation, with particular reference in each case to the changes occurring in the sediments under partially or totally anaerobic conditions, and the effects of these changes on the supernatant water. It is concluded that the changes in the sediments are always undesirable and the cumulative effects of the various changes affect the quality of the supernatant water adversely. It is therefore recommended that the regular sampling of water should be replaced by sampling of both water and sediments.—WPA

DISINFECTION

Problems of Water Treatment With Ozone. W. HOFF. *Literaturber. Wasser, Abwasser, Luft u. Boden* (Ger.), 7:188 ('58). The author describes expts. in Dusseldorf where tests were made of different types of ozone plant and different mixing and distributing equipment. The use of high concns. of ozone (25-35 g/cum of air) gave good results and the extra cost of power was balanced by saving in the treatment of air and losses in waste air. Using a new type of mixing jet and high concns. of ozone, the ozone was practically completely effective and the waste air loss was less than 1%. By this method the ozone dissolved rapidly so that the contact time could be reduced to a fraction of that usually required. The size of plant and thus the capital cost could be reduced. Ozone improves the color, odor, and taste of water. Water containing fine suspended matter can be disinfected with small amounts of ozone whereas large amts. of chlorine would be required.—WPA

Bacteriologic Disinfection of Water Supply Wells by Use of the Catadyn Process. H. EHREMAN. *Bohrtechn. Brunnenbau* (Ger.), 9:368 ('58). After a description of the commonly unsatisfactory bacteriologic conditions of wells for house and school supplies, the author describes the oligodynamic action of silver on bacteria and different methods of disinfection with Catadyn-Micropur. Instructions are given for the disinfection of pold. wells. On the evening of 1 day a soln. containing 100 g of Micropur per cum of water in the well is poured in and left to act overnight; on the evening of the second day the treatment is repeated with a soln. containing 50 g of Micropur per cu m. Continuous treatment then consists in adding, generally on an evening of the weekend, 10 g of Micropur per cu m of the 7-day water demand. If the water demand is greater than the content of the well, treatment must be more frequent. For heavily pold. wells, an oxidizing agent should also be used. For disinfection of small swimming baths, 10 g of Micropur per cu m of water should be added at the first filling, and thereafter the water should be treated weekly with 5 g per cu m.—WPA

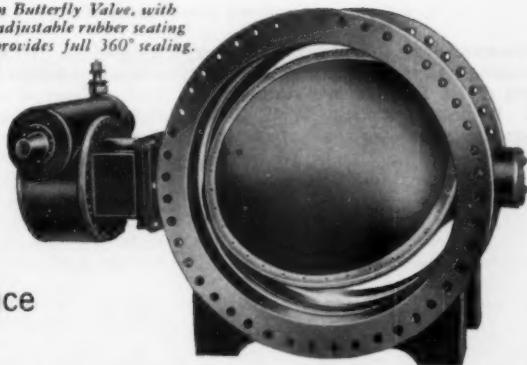
Electrolytic Disinfection of Water. *Sanit. Tech. (Berlin)*, 23:4:146 ('58). Apparatus is described in which, by electrolysis, soda lye and chlorine are produced from a 20-25% soln. of sodium chloride. The chlorine can then be added to water by an ejector. As the anode and cathode spaces are separated by a diaphragm, the soda lye can be used for other purposes. The capacities of small and large plants and power requirements are given.—WPA

Disinfection of Water Wells. Y. S. SURENYANTS. *Vodosnabshenie i Sanit. Tekh. (USSR)*, 8:24 ('59). Well H_2O contaminated during the drilling operations or as a result of construction defects can be made fit for drinking after the cause of contamination has been eliminated. This is done by treatment with Ca hypochlorite soln. contg. 50 mg active Cl/l. The technique of scrubbing the well pipes and introducing the disinfectant and the necessary equipment are described. The quantity of hypochlorite needed to prep. a given vol. of soln. of the desired active Cl concn. can be detd. from a nomogram.—CA

(Continued on page 86 P&R)

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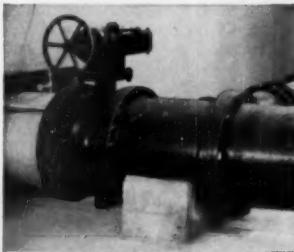


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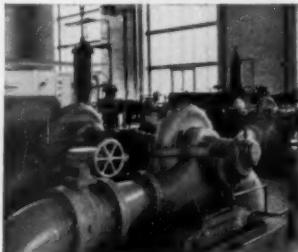
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(Continued from page 84 P&R)

Experimental Basis for Addition of Silver to Drinking Water With Special Considerations of Its Relation in Treatment of Rural Domestic Waters With Silver Preparations. W. OBERZILL. *Arch. Hyg. u. Bakteriol. (Ger.)*, 141:217 ('57). Lab. studies were conducted on the disinfection of water considering the role of Ag concn., temp. of water, phys. and chem. characteristics of water from various sources, types of organism present, and decrease in Ag concn. Use of Ag under inappropriate conditions resulted in improper disinfection.—CA

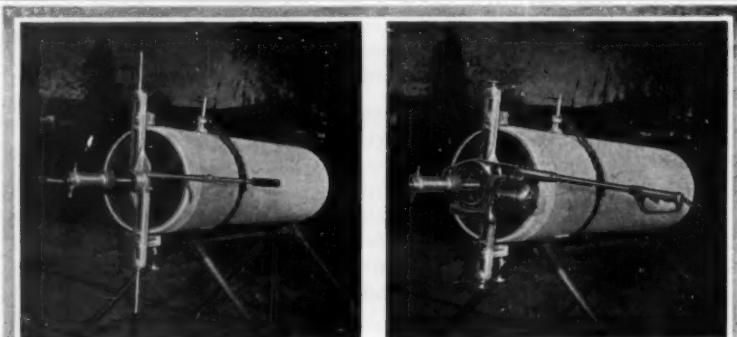
CORROSION

Behavior of Carbon and Stainless Steels in Acid Waters. R. J. SCHMITT. *Corrosion*, 14:445t ('58). The suitability of carbon steel as a condenser tube material depends mainly on the deposition of protective scales by the water. When fresh water becomes contaminated with acid drainage,

the tendency for such scales to form is destroyed, and rapid corrosion occurs. Where large volumes of water are used in a once-through system, treatment of the water other than addn. of lime to raise the pH value is uneconomic. The author describes experiences at a plant where severe corrosion of carbon steel tubes in the wash-oil condenser occurred within 4 mo; these have now been replaced by stainless-steel tubes which show no sign of attack after 6 mo.—WPA

Filming Amines Control Corrosion in Utility Plant Condensate System. E. E. GALLOWAY. *Corrosion*, 15:8:99 ('59). The use of filming amine (an octadecylamine derivative) led to the following conclusions: Filming amine will form a protective film on metal surfaces in low pressure condensate systems. This film is evident in condensers and feedwater piping. The film gives protection against CO_2 and O corrosion. Filming amine treatment offers protection to systems used frequently for

(Continued on page 88 P&R)



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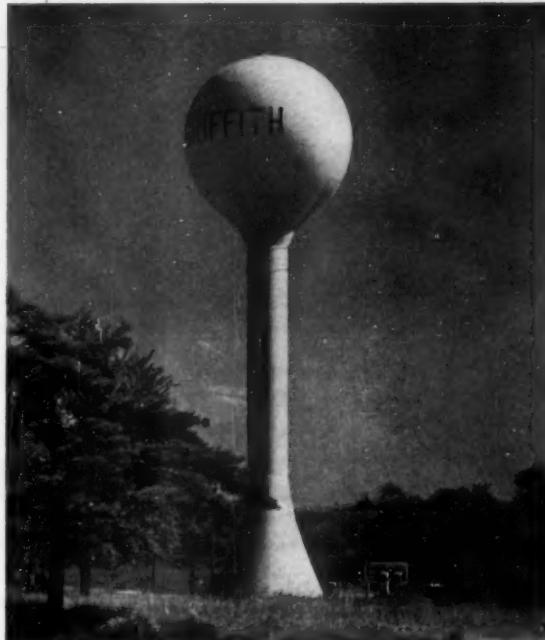
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(Continued from page 86 P&R)

stand-by service owing to protection against O. Filming amine has no adverse effect on Cu and Cu alloys, and may even offer some protection. Filming amine does not cause objectionable dislocation of corrosion products when feed rate is increased slowly. When fed at rates sufficient to protect the condensate system, it does not offer proper protection to wet areas of turbines.—CA

Automatic Corrosion Controls in Steam Lines of a High Pressure Steam Power Station. J. PIROTTE. *Journee Automatisation* (Liege), 64 ('58). Continuous detn. of H, O, dissolved solids, and pH by automatic equipment at the Schelle power station is described, along with regulating devices such as that for pH control by using volatile amines. This type of regulation requires adoption of special techniques to protect against priming and leakage.—CA

OTHER ARTICLES NOTED

Recent articles of interest appearing in periodicals of the water supply field are listed below.

"Coagulant Choice—Key to Efficiency." JOHN S. HESS. *Am. City*, 75:8:161 (1960).

"Battery of Two-Inch Meters Replaces Old Compound Meter." H. F. SEIDEL & R. L. JOHNSON. *Wtr. Wks. Eng.*, 113:719 (1960).

"Ten Years of Cathodic Protection for Large Water Storage Tanks." H. M. PATTON JR. *Corrosion*, 16:8:12 (1960).

"The Mechanism of Protective-Scale Formation on Copper-Base Alloys." J. C. BLADE & A. PREECE. *J. Inst. Metals* (Gr. Br.), 5:10:427 (Jun. 1960).

"Emergency Public Works Services in Civil Defense." BARENT F. LANDSTREET. *Public Works*, 91:8:114 (1960).

"Limnology and Quality of Raw Water in Impoundments." C. M. WEISS & R. T. OGLESBY. *Public Works*, 91:8:97 (1960).

"Practical Electricity in the Plant." MARDEN C. SMITH. *Wtr. & Sew. Wks.*, R-68 (Sep. 15, 1960).

"Feather River Plan Gets Support." LAURESS L. WISE. *Eng. News-Record*, 165:4:23 (1960).

"Canada's Biggest Earthfill Goes Year Round." G. A. MACKENZIE. *Eng. News-Record*, 165:5:34 (1960).

"Brazil's Tres Marias Project Puts Rio Sao Francisco to Work." A. N. RYDLAND. *Eng. News-Record*, 165:6:42 (1960).

"Calcite Coating Protects Water Pipes." R. F. McCUALEY. *Wtr. & Sew. Wks.*, 107:276 (1960).

"A Laboratory Study of Sulfamic Acid as a Vehicle for Chlorine." JOSEPH A. McCARTHY. *J. NEWWA*, 74:2:166 (Jun. 1960).

"Vacuum-Type Diatomite Filters in Water Treatment." HENRY N. ARMBRUST. *J. NEWWA*, 74:2:143 (Jun. 1960).

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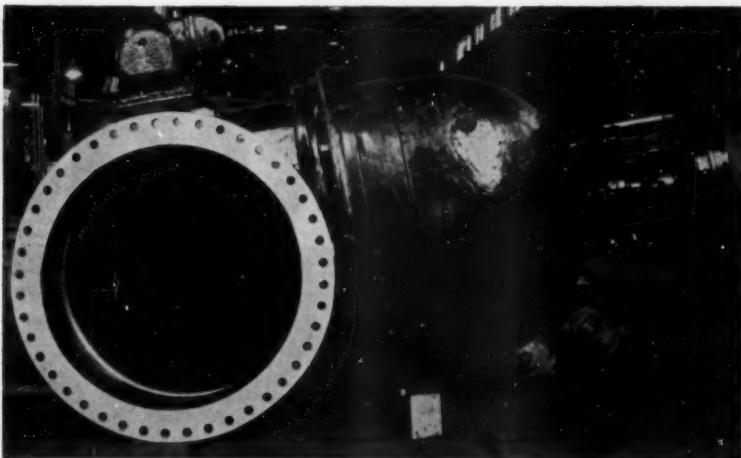
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Those are the comments of Louis Gulfo, partner with Mike and James Bertilacci in G&B Construction, Inc. They installed "K&M" Asbestos-Cement Pressure Pipe in bitter cold, during February and March 1960. However, neither rain, snow, nor mud interrupts the installa-

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Keasbey & Mattison at Ambler

Left to right: Louis Gulfo, G&B Construction, Inc.; Dale McCleary, sales manager, Trumbull Plumbing Supply Co.; James Bertilacci, G&B Construction, Inc.; Burke Lyden, Asst. Chief Engineer, Youngstown, Water Dept.; Jim Bisciglia, Asst. Engineer, Mahoning County, and J. Henry Painter, Trumbull Supply Company.



3 miles of 16" "K&M" Asbestos-Cement Pressure Pipe were installed. Here, we see it ready for installation along Webb Road, in Austintown Township. In branching from the 16" water line, Mahoning County used 1 mile of 12" "K&M" Asbestos-Cement Pressure Pipe and ½ mile of 8" "K&M" Asbestos-Cement Pressure Pipe. Specifications call for 90 lbs. pressure when line is in operation serving 16,000 residents.





The Reading Meter

Research Inventory of Active Projects (1958) in Water Supply and Pollution Control. *Public Health Service Publication No. 768, Office of Research Grants Coordinator, Div. of Engineering Services, USPHS, Washington 25, D.C. (1960) 72 pp.; free*

This inventory, summarizing data on 280 water supply and pollution control research projects active in the United States during 1958, is intended as a source of information on projects for those administering and for those conducting research. The booklet is divided into three main sections: a listing of research projects by states, describing briefly where the project is located, what is being investigated, and who is directing the research; an extensive subject index arranged by research areas; and an address list of those reporting on the project.

The research projects are largely conducted in universities (73.2 per cent) with the remainder nearly equally divided between state, federal, industrial, and local agencies. The largest amount of support (53.6 per cent) for research projects is supplied by federal agencies, followed by state, industrial, university, and local agencies, in that order.

Basic Water Works Manual. *Robert J. Sweitzer, with chapters by M. E. Flentje & F. B. Smith. American Concrete Pressure Pipe Assn., 228 N. LaSalle St., Chicago 1, Ill. (1958) 182 pp.; free*

This book begins with a brief history of water supply and a discussion of the

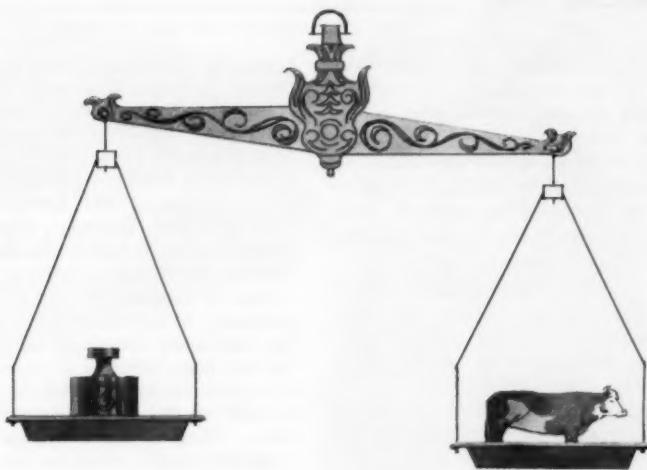
hydrologic cycle, followed by a description of the various sources of water supply and the methods of transmission and distribution. Practical information on services, meters, and pumping is included. The chapters on basic hydraulics and hydraulic testing are supplemented by Hazen-Williams flow charts for pipe sizes of 2-144 in. The chapter on utility economics and financing is quite detailed and enlarges the scope of the manual. This information will be of interest to those with the responsibility of arranging financing for water supply projects.

The manual contains a substantial number of tables and charts, as well as a glossary of technical terms related to the technical aspects of water supply. These, along with the broad scope and practical nature of the manual, make it a book which should be particularly useful to sanitary engineers and utility operators.

Manual on Industrial Water and Industrial Waste Water. *ASTM Special Technical Publication No. 148D, American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. (2nd ed., 1960) 670 pp.; \$11*

Within the past year, AWWA has established an official liaison with ASTM Committee D19 on Industrial Water. Unofficially, a number of AWWA members have been working on this committee for many years and are among the anonymous contributors to this manual. The new edition of the manual is a completely rewritten version of the first edition, which was published in 1953 and

(Continued on page 94 P&R)



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The Reading Meter

(Continued from page 92 P&R)

subsequently reprinted three times with additional and revised ASTM methods pertaining to water. The new edition has the first complete revision of the editorial material, which now comprises about one-third of the book. Information on industrial waste water has been added, as has a completely new chapter on radioactive nuclides in water.

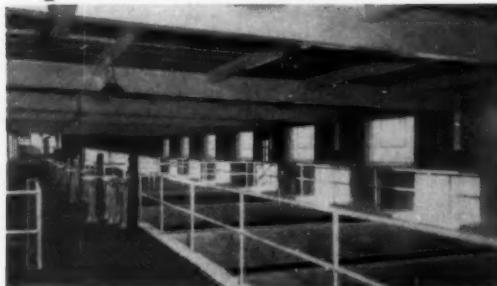
The descriptive chapters have been designed to present a broad survey of problems encountered in the use, treatment, sampling, and analysis of industrial water and waste water, rather than to provide a detailed reference work on this subject.

The following list of chapter headings in this section suggests the scope of Part I: Uses of Industrial Water, Effects of Impurities on Water Uses, Self-Purification of Streams, Composition and Classi-

fication of Industrial Water and Water-Formed Deposits, Treatment of Process Water and Waste Water, Sampling and Flow Measurement of Industrial Water and Industrial Waste Water, Analysis of Industrial Water and Industrial Waste Water, Sampling and Identification of Water-Formed Deposits, Analysis of Water-Formed Deposits, and Radioactive Nuclides in Water.

Part II includes all ASTM standards pertaining to water through 1959 including definitions, sampling methods, corrosivity tests, methods of reporting, and determination of precision of methods, as well as the actual analytical procedures. Many of the latter apply to concentration ranges which are not normally encountered in laboratories dealing primarily with water supplies for municipal use.

(Continued on page 96 P&R)

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The Reading Meter

(Continued from page 94 P&R)

This manual deserves a place alongside *Standard Methods* in every water laboratory. The descriptive chapters should be read by all chemists concerned with the analysis, treatment, and use of water for either municipal or industrial applications.—SIDNEY SUSSMAN, *Water Service Laboratories, Inc.*, New York.

Inventory of Municipal and Industrial Waste Facilities. *Public Health Service Publication No. 622, Government Printing Office, Washington 25, D.C. (1959) nine volumes; \$10.25*

This publication is a listing of physical and operating data on all municipal and some industrial waste treatment facilities in the United States, as of Jan. 1, 1958. It consists of nine volumes, corresponding to the nine administrative regions of the Department of Health, Education & Welfare.

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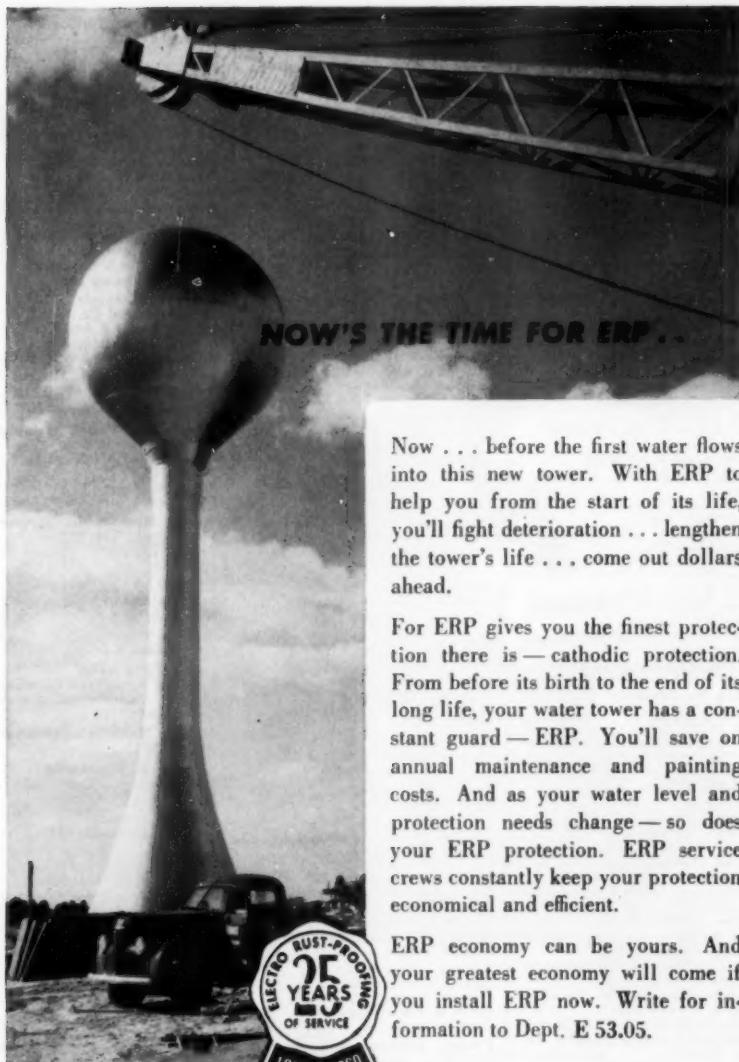
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Pipe, Concrete:
American Pipe & Construction Co.
Lock Joint Pipe Co.
Vulcan Materials Co.

Pipe, Copper:
American Brass Co.

Pipe, Plastic:
American Hard Rubber Co.
Keasbey & Mattison Co.
Morgan Steel Products, Inc.
Orangeburg Mfg. Co., Div. of The Flintkote Co.

Pipe, Steel:
Armcro Drainage & Metal Products, Inc.

Bethlehem Steel Co.
Morgan Steel Products, Inc.
Southern Pipe Div. of U.S. Industries

Pipe Cleaning Services:
Centriline Corp.
National Water Main Cleaning Co.

Pipe Coatings and Linings:
American Cast Iron Pipe Co.
American Hard Rubber Co.

Centriline Corp.
Inertol Co., Inc.

Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.
Reilly Tar & Chemical Corp.
Southern Pipe Div. of U.S. Industries

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Pilot Mfg. Co.

Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.
Wheeler Mfg. Corp.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators; see Locators, Pipe

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Golden-Anderson Valve Specialty Co.
Mueler Co.

Ross Valve Mfg. Co.

Pumps, Boiler Feed:
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works

DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
B-I-F Industries, Inc.—Proportioners

Fischer & Porter Co.
Precision Chemical Pump Corp.
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works

Fiese & Firstenberger
Layne & Bowler, Inc.
Peerless Pump Div.

Pumps, Diaphragm:
Dorr-Oliver Inc.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Peerless Pump Div.
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
Fiese & Firstenberger
Layne & Bowler, Inc.
Peerless Pump Div.

Recorders, Gas Density, CO₂, NH₃, SO₂, etc.:
Fischer & Porter Co.

Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
Bailey Meter Co.
B-I-F Industries, Inc.—Builders

Fischer & Porter Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves; see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
Eimco Corp., The
General Filter Co.
Infico Inc.
Permutit Co.

Sodium Aluminate:
Nalco Chemical Co.

Sodium Chloride:
International Salt Co., Inc.

Sodium Fluoride:
American Agricultural Chemical Co.
General Chemical Div., Allied Chemical Corp.

Sodium Hexametaphosphate:
Calgon Co.

Sodium Hypochlorite:
Jones Chemicals, Inc.
Wallace & Tiernan Inc.

Sodium Silicate:
General Chemical Div., Allied Chemical Corp.
Philadelphia Quartz Co.

Sodium Silicofluoride:
American Agricultural Chemical Co.
General Chemical Div., Allied Chemical Corp.
Tennessee Corp.

Softeners:
Dorr-Oliver Inc.
General Filter Co.
Hungerford & Terry, Inc.
Permutit Co.

Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon Co.
General Filter Co.
International Salt Co., Inc.
Nalco Chemical Co.

Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

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Steel Plate Construction:

Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.

Stops, Curb and Corporation:

Ford Meter Box Co.
Hays Mfg. Co.
Mueller Co.

Storage Tanks: see Tanks

Strainers, Suction:
James B. Clow & Sons
R. D. Wood Co.

Surface Wash Equipment:
Golden-Anderson Valve Specialty Co.
Permitit Co.

Swimming Pool Sterilization:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioners
Fischer & Porter Co.
Wallace & Tiernan Inc.

Tank Painting and Repair:

Koppers Co., Inc.
National Tank Maintenance Corp.

Tanks, Prestressed Concrete:
Preload Co., Inc.

Tanks, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.

Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.

Taste and Odor Removal:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Proportioners
General Filter Co.
Industrial Chemical Sales Div.
Permitit Co.
Wallace & Tiernan Inc.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.

Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
M & H Valve & Fittings Co.
Mueller Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.

Valves, Altitude:

Allis-Chalmers Mfg. Co., Hydraulic Div.
Golden-Anderson Valve Specialty Co.
Ross Valve Mfg. Co., Inc.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
Allis-Chalmers Mfg. Co., Hydraulic Div.

B-I-F Industries, Inc.—Builders

James B. Clow & Sons

DeZurik Corp.

Kennedy Valve Mfg. Co.

M & H Valve & Fittings Co.

Mueller Co.

Pelton Div., Baldwin-Lima-Hamilton

Henry Pratt Co.

Rockwell Mfg. Co.

R. D. Wood Co.

Valves, Detector Check:
Hersey-Sparling Meter Co.

Valves, Electrically Operated:
Allis-Chalmers Mfg. Co., Hydraulic Div.

B-I-F Industries, Inc.—Builders

James B. Clow & Sons

Darling Valve & Mfg. Co.

Golden-Anderson Valve Specialty Co.

Kennedy Valve Mfg. Co.

M & H Valve & Fittings Co.

Mueller Co.

Henry Pratt Co.

Rockwell Mfg. Co.

A. P. Smith Mfg. Co.

R. D. Wood Co.

Valves, Float:

James B. Clow & Sons

Golden-Anderson Valve Specialty Co.

Henry Pratt Co.

Rockwell Mfg. Co.

Ross Valve Mfg. Co., Inc.

Valves, Gate:

James B. Clow & Sons

Darling Valve & Mfg. Co.

Dresser Mfg. Div.

Kennedy Valve Mfg. Co.

M & H Valve & Fittings Co.

Mueller Co.

A. P. Smith Mfg. Co.

R. D. Wood Co.

Valves, Hydraulically Operated:

Allis-Chalmers Mfg. Co., Hydraulic Div.

B-I-F Industries, Inc.—Builders

James B. Clow & Sons

Darling Valve & Mfg. Co.

DeZurik Corp.

Golden-Anderson Valve Specialty Co.

Kennedy Valve Mfg. Co.

F. B. Leopold Co.

M & H Valve & Fittings Co.

Mueller Co.

Pelton Div., Baldwin-Lima-Hamilton

Henry Pratt Co.

Rockwell Mfg. Co.

A. P. Smith Mfg. Co.

R. D. Wood Co.

Valves, Large Diameter:

Allis-Chalmers Mfg. Co., Hydraulic Div.

James B. Clow & Sons

Darling Valve & Mfg. Co.

Golden-Anderson Valve Specialty Co.

Kennedy Valve Mfg. Co.

M & H Valve & Fittings Co.

Mueller Co.

Pelton Div., Baldwin-Lima-Hamilton

Henry Pratt Co.

Rockwell Mfg. Co.

A. P. Smith Mfg. Co.

R. D. Wood Co.

Valves, Regulating:

Allis-Chalmers Mfg. Co., Hydraulic Div.

DeZurik Corp.

Golden-Anderson Valve Specialty Co.

Mueller Co.

Henry Pratt Co.

Rockwell Mfg. Co.

Ross Valve Mfg. Co.

Valves, Swing Check:

James B. Clow & Sons

Darling Valve & Mfg. Co.

Golden-Anderson Valve Specialty Co.

M & H Valve & Fittings Co.

Mueller Co.

Rockwell Mfg. Co.

A. P. Smith Mfg. Co.

R. D. Wood Co.

Venturi Tubes:

B-I-F Industries, Inc.—Builders

Rockwell Mfg. Co.

Simplex Valve & Meter Co.

Waterproofing:

Inertol Co., Inc.

Koppers Co., Inc.

Plastics & Coal Chemicals Div., Allied Chemical Corp.

Water Softening Plants; see Softeners

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
LaMotte Chem. Products Co.

Wallace & Tiernan Inc.

Water Treatment Plants:

American Well Works

Chain Belt Co.

Chicago Bridge & Iron Co.

Dorr-Oliver Inc.

Eimco Corp., The

General Filter Co.

Hungerford & Terry, Inc.

Infico Inc.

Permitit Co.

Pittsburgh-Des Moines Steel Co.

Roberts Filter Mfg. Co.

Walker Process Equipment, Inc.

Wallace & Tiernan Inc.

Well Drilling Contractors:
Layne & Bowler, Inc.

Well Reconditioning and Formation Testing:

Halliburton Co.

Layne & Bowler, Inc.

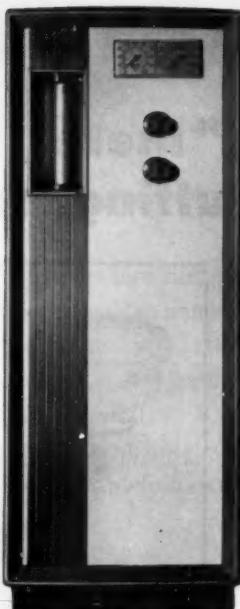
Wrenches, Ratchet:

Dresser Mfg. Div.

Zeolite: see Ion Exchange Materials

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from water system of South Salt Lake City, Utah

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